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CYCLOPÆDIA:

OR, A NEW

UNIVERSAL DICTIONARY

OF

ARTS and SCIENCES.

Montgomeryshire

MONTGOMERYSHIRE, one of the counties of North Wales, is bounded on the E. and N.E. by the county of Salop in England; on the S.E. by Radnorshire; on the W. and S.W. by Merionethshire and Cardiganshire; and on the N. by Denbighshire. It extends, according to the most accurate surveys, 35 miles in length, from the farthest point of Llangurig, on the borders of South Wales, to Pistyll-Rhaiadr, a noted cataract in the Berwyn hills; and in breadth, from the town of Montgomery to that of Machynlleth, 30 miles. The superficial area is variously stated; Templeman making it to comprise 444,800 acres, while by other computation it is fixed as high as 560,000; and again, in a very recent survey, at 491,600. Of this extent only 60,000 acres are under cultivation, and 18,000 laid down in pasturage; the remainder of the county is either in a waste condition or is appropriated to woodlands.

The first inhabitants of this district, of whom mention is made in history, were a portion of the Ordovices, or Ordovicæ, whose territories extended at one time over the whole six counties of North Wales, with the exception of a small part of Flintshire, which belonged to the Carnabii. This people, naturally brave, and defended by the lofty hills and almost impassable ravines, with which their country abounds, contrived, notwithstanding their deficiency in military skill, to baffle, for a period of two centuries, all the efforts of Roman discipline and courage to subdue them. Julius Agricola, the celebrated general of Domitian, however, at last effected, by his consummate and indefatigable conduct, what his predecessors had in vain attempted; and not only compelled this county, but the most remote corner of Wales, to acknowledge and submit to the Roman yoke. But though conquered, their ancient valour and love of country still continued to animate them, so that no sooner were the mighty conquerors of Europe forced to abandon their distant provinces and concentrate their troops for the defence of Italy, than the natives again asserted their independence.

At this period, however, their country became divided into two separate kingdoms, or principalities; of which Powisland was, for many years, the most powerful and extensive; and included Montgomeryshire. During the heptarchy many desperate battles were fought, either within this county, or on its borders; especially in the reign of Offa, king of Mercia, who, having routed the Powysians in several actions, compelled them to abandon all their possessions in Shropshire; and in order the more effectually to restrain their incursions, built the celebrated "dyke," which is still visible at the eastern boundary of the county. Though thus restrained, however, the Powysian monarchs, who now fixed their residence at Mathraval, in the vale of Meivod, still continued to be objects of terror to their Mercian neighbours. The dyke of Offa was frequently a scene of the most dreadful carnage. At Buttington, the generals of the great Alfred completely destroyed a large body of Danes, who, having penetrated through Mercia, had posted themselves here upon the approach of the Saxon army. By this time the integrity of the kingdom of Powisland had been again invaded, by its separation into two smaller principalities, of which Montgomeryshire alone formed that distinguished by the name of Powis-Wenwynwyn. This district, subsequent to the Norman conquest, shared the fate of all the border counties, being compelled to submit to the feudal domination of the lords marchers, after a long and desperate struggle to maintain its liberty. It still continued, however, to be distinguished by its ancient name, till the division of Wales into counties, in the reign of Henry VIII., when it received the appellation of Montgomeryshire, from the town of Montgomery, which forms the subject of the preceding article.

The greater proportion of this county assumes a mountainous characteristic. This is particularly the case with the midland, western, and south-western parts, which are extremely bleak and unfavourable to cultivation. A range of

mountains, commonly distinguished by the title of "the back-bone of Montgomeryshire and Merionethshire," commences in the south-western district, and running nearly through the whole shire, in a curvilinear direction, enters the county of Merioneth near Aran Fowddwy. The Freiddin, or Bridden hills, and the Long mountain, rear their lofty heads on the eastern side of the county, and form a natural boundary throughout their extent, between it and Shropshire. The Biga mountains are seen on the north, stretching themselves along the northern side of the valley of the Severn, till they reach a collateral ridge of Plinlimmon. Besides these there are numerous inferior ranges, usually separated by long narrow vallies and a few isolated hills, which rise to a very considerable height, like artificial mounts, in the centre of a level tract of country. The substrata of these hills vary, but not so much as in the adjacent counties. Limestone rarely enters into their composition, except in the vicinity of Llanymech and Porthwaun, at both of which places a considerable quantity of lime is wrought, chiefly for the purposes of manure. Slate strata, on the other hand, are very abundant, and indeed constitute the principal portion of all the mountains in the county, which are not pre-eminently lofty. Many quarries have been opened in different districts for the manufacture of this material, but the principal ones are confined to the hills around Llangynnog, where the best slates, perhaps in England, are procured. From the elevated situation of these quarries, the conveyance of the slates from thence to the plain below is a task of considerable difficulty and hazard. The method in use here to accomplish that object is not a little remarkable, and to an observer unaccustomed to the sight, must appear fraught with extreme danger. The slates are placed on a small sledge, adapted to the work, which is fastened to the shoulders of a man who has the care of delivering the cargo at the base of the mountain, by means of a rope, of which he lays fast hold with both hands, and then turning his face towards the load, he begins to move, gradually receding backwards till he reaches the bottom. Apparently dangerous, however, as this operation is, long experience has rendered it so familiar to the workmen in general, that accidents are very uncommon; and to many of them it is equally easy as conducting a common wheel-barrow on level ground. The other mineral productions of this county are coal, silver, lead and copper. The coal mines are only found, in any considerable quantity, at Coedwae, on the borders of Salop. Silver is most plentiful at Esgair-hir, where, as well as at Graig-y-Mwyn, near Piftyll-Rhaiadr, Dolydan west from Llanbrynmair, and Llanydloes, lead mines have been opened. The only copper mine is situated in the vicinity of Esgair-hir, on the confines of Cardiganshire.

Montgomeryshire is abundantly supplied with rivers; indeed it may justly be said that more streams take their rise in this county than in any other of similar extent in Great Britain. Of these rivers the principal are the Severn, the Wye, the Vyrnwy, and the Tanat. The Severn, rising on the side of Plinlimmon hill, runs in a north-easterly direction through a very considerable portion of the county, and during its course receives the waters of several auxiliary streams. The Wye, which likewise has its source from the same ridge, taking a south-east direction, is joined by the Bedw rivulet at Llangerrig; whence flowing more to the south it soon enters Radnorshire. The Vyrnwy rises near Bwlch-y-Groes, and after a very changeable course, during which it is joined by the Tanat, falls into the Severn near Llandrinio. This river is remarkable for the multiplicity and variety of fish which frequent it. Of those rivers which pass through the county, but have their springs in another, the principal are, the Maw,

the Traethbach, the Cieriog, the Dee, and the Dovey: all of which will be found more particularly noticed in our account of the respective counties to which they seem more properly to belong, under their appropriate names.

The climate of this county varies in different districts. In those parts which have been mentioned as more elevated than the rest, it is extremely cold and bleak; and in the narrow vallies the wind is almost constantly high, and very frequently boisterous. The westerly winds are prevalent during nine months of the year, and the easterly the remaining three. These last are usually accompanied with fleet and rains, but seldom blow so strong as those from the S.W. or N.W. which commonly prove fatal to the fruit both on the higher grounds and in the vallies. The soil of the mountains here, partaking of the nature of their substrata, is for the most part of a schistose kind; that in the vales was doubtless originally of the same description, but in consequence of cultivation now approaches very nearly to a clayey substance.

It has already been observed, that not above one-half of Montgomeryshire is in a state of cultivation, the rest being either covered with wood, or lying in a waste condition. Of the cultivated lands, about one-third has been mentioned as arable; the other two-thirds being usually laid down with grass. The most common arable crops are oats, barley, wheat and rye. Hemp is likewise grown in considerable quantity in the eastern division of the county; almost every cottage having what is called a hemp-yard attached to it. Of the grass lands only a small portion, compared with their extent, are sufficiently fertile to be adapted for fattening cattle. Indeed that object is seldom attempted, except in some particular spots in the vales of the Severn, and of the Vyrnwy. The woodlands comprehend several very valuable and extensive plantations. Montgomeryshire, in fact, is still by far the best wooded county in Wales, and was formerly regarded as a valuable depôt of oak for the use of the navy. Within the last fifty years, however, large quantities of that noble tree have been felled; and so little care taken to replace them, that the county has nearly lost all its importance in this respect. The waste lands here are chiefly appropriated to the grazing of oxen, sheep, and horses. The oxen are of different breeds, each of which have their provincial peculiarities. Those of the native breed, which are usually termed the finch-backed kind, are of a brindled colour, short in the leg, and of great depth in the carcase. Those originally from Devonshire have, on the other hand, long legs, and a more compact body, and are consequently better fitted for agricultural purposes than the native sort. A kind from Hereford, distinguished by their white faces, have of late years become very prevalent in the eastern district. Of sheep there are two kinds; the one peculiar to the Kerry hills, and the other chiefly bred on the ridge called Long-Mountain, and some other hills on the borders of Shropshire. The first of these breeds is supposed to be the only variety in Wales which produces perfect wool; that of the other breeds being usually more or less debased by the intermixture of coarse long hairs, denominated by dealers kemps. Its discriminating characteristics are large wide cheeks, covered with wool, a bunchy fore-head, destitute of horns, white woolly legs, and a broad beaver-like tail. The second kind also affords wool of a superior quality, but in much less quantity. Horses of very different sizes and properties are reared in Montgomeryshire. The hilly districts are remarkable for a race of small ponies, called merlins, which being left to range over the mountains, as well during winter as summer, till at least three years old, are in consequence a very hardy race. These are chiefly used as beasts of burthen, by the numerous packmen who traverse the country to collect the

MONTGOMERYSHIRE

manufactured articles, or to sell others which the inhabitants may require. For this purpose they are extremely well fitted, custom having taught them to climb the rugged and slippery ascents with a firm and steady step; and it is on that account much to be lamented, that the neglected state in which they are allowed to remain has materially deteriorated the breed. A larger kind of horse, apparently a cross between the merlyn and the English breed, is likewise a native of the hilly districts in Montgomeryshire. The most sizeable of these animals are admirably adapted for the team on the higher grounds, where heavier horses would be egregiously misapplied; and the lesser ones make good roadsters with a light weight. A third breed, of a very superior quality to either of these, is also reared in the more fertile vales here, which some say was introduced from Spain by Robert, earl of Shrewsbury. Queen Elizabeth is further stated to have greatly assisted in perpetuating this breed, by keeping a famous stud of horses and brood mares at Park, in this county.

The chief, or rather the only, manufactured production of Montgomeryshire, is flannel; for though hemp, as has been already said, is grown here in considerable quantity, it is seldom made into any article of use, till it has passed into the hands of the manufacturers of other districts. In former times, the only machinery employed in the manufacture of the flannel was the common weaving machine; all the process of carding the wool, and spinning into thread, having been executed, in the most literal sense of the term, by the tedious operation of the hand, by farmers and cottagers in their own houses. Of late years, however, the powerful aid of more complicated apparatus has likewise been resorted to; and there are now upwards of forty carding, and several spinning machines, driven by water, in different parts of the county. The most extensive manufactories for weaving are those at Newtown, Berhiew, Welsh-Pool, and Dolydran; and one on the Dulas stream, near Machynlleth, at which, however, cloths are made as well as flannels. Of these last the finer pieces generally measure about 132 yards, and the inferior ones 110: and as 500 pieces of either kind are frequently sold at the weekly markets, it does not seem to be exceeding truth to average their amount at 300, thereby making the whole annual produce sold out of the county 7800 pieces; which, calculated at the low average of 8*l.* a piece, gives the sum of 62,400*l.* as the total profit arising therefrom, including the value of wool, which may be supposed worth something more than 18,000*l.*

The roads in this county are, perhaps without exception, the worst within the limits of North Wales, especially in the vallies; but this deficiency does not arise so much from any neglect on the part of the proprietors to their formation or repair, as from the want of suitable materials for the purpose; there being no granite or other indurated rock here, as in the other counties, which could be employed to render them firm and compact. They are consequently most commonly formed of the shale and slate stones, of which it has been remarked that the mountains are chiefly composed; and these soft and friable substances soon become reduced, by the pressure and friction they necessarily sustain, to their primitive clay. Hence the roads, even in summer, are often moist and slippery; and in winter are so deep and clammy, as to be nearly impassable for carts of a heavy burthen. But to the honour of the county, though the roads are thus unavoidably of a bad texture, the bridges are generally excellent, and more numerous than those of any other county in the principality, when considered in reference to the comparative extent of its cultivated lands.

Many interesting remains of antiquity of various descrip-

tions have been discovered or traced, at different periods within the limits of Montgomeryshire. The Roman station, Mediolanum, is fixed by several able antiquaries in the vicinity of Meifod, or Meivod, which, as noticed above, afterwards became the residence of the Powysian monarchs. The station Maglona is likewise, with great probability, placed at or in the vicinity of Machynlleth, as many vestiges of walls, and the remains of two forts evidently Roman, are still distinctly visible there. Many Roman coins have also been dug up at this place; and two miles from it is a spot, yet retaining the appellation of Cefn Caer, or the back part of the city. Machynlleth afterwards became noted as the town where the celebrated Owen Glyndwr assembled the estates of Wales in 1402, when his title to the principality was solemnly acknowledged. The senate house, in which this convocation was held, is now degraded, by being converted into a stable; but its spacious door-way sufficiently evinces its occupancy to have been once more honourable. (See MACHYNLLETH.) At Montgomery are the ruins of the celebrated castle of that name; and close to it is a British and a Saxon encampment, the former remarkable both for its strength and extent. On the west side of the road from this town to that of Newtown stands the ancient fortress of "Dolforwyn-Castle," said by Dugdale to have been the work of Dafydd-ap-Llewelyn, a prince who reigned from the year 1240 to 1246; but referred by a Welsh writer, John Dafydd Rhys, to a much earlier date. Caer-Sws, or Caers-goose castle, on the north bank of the Severn, is considered by some to have been a Roman station, though not mentioned in any of the Itineraries. Extensive traces of buildings, ranged in streets intersecting each other at right angles, have been discovered in the fields, adjacent to the village. Two encampments are situated at a little distance, where some inscribed bricks have been dug up; and close to them appear considerable vestiges of a Roman road, running in a direction from Caer-Sws to Meifod. Several encampments, both Roman and British, are likewise discovered in the neighbourhood of Llanfair and Welsh-Pool. Near the latter town was situated the abbey of Ystrad-Marchell, founded in 1170, for monks of the Cistercian order. A mile from hence is Powis castle, a venerable mansion, constructed of red sand-stone, and standing on the ridge of a lofty rock. This castle makes a considerable figure on the pages of history, and is now the chief seat of the noble family of Clive, to which the adjoining village gives the title of marquis. (See WELSH-POOL.) Besides these, many other relics of antiquity in Montgomeryshire might be noticed, would the limits of an article like the present allow of greater digression; but as that cannot be permitted, we shall only further mention the "Dyke of Offa," which runs nearly through the whole eastern side of the county, and which is justly ranked among the most extraordinary efforts of human labour in Great Britain.

Montgomeryshire, in a political point of view, is divided into nine hundreds, comprising forty-nine parishes, one borough-town, Montgomery, and six market-towns, *viz.* Welsh-Pool, Llanfyllin, Llanfair, Machynlleth, Newtown, and Llanydros. The names of the hundreds are Llanfyllin, Denoddwr, Pool, Cawrfe, Mathrafal, Machynlleth, Llanylloes, Newtown, and Montgomery. This county sends two representatives to parliament, one as knight of the shire, and another as burgess for the borough. Its honorial distinctions are confined to two families; that of Clive, already mentioned, and that of Herbert, which holds the dignity of earl of Pembroke and Montgomery. By the returns made to parliament in 1801, the amount of its population was 47,558 persons, *viz.* 22,494 males, and 25,064 fe-

males; of which number, 6233 were reported as employed in the various departments of trade and manufacture, and 13,082 in the labours of agriculture. The money raised here for the use of the poor, in 1803, amounted to the sum of 22,988*l*. In respect to ecclesiastical jurisdiction, the

whole county is included within the province of Canterbury, but is divided among the three dioceses of Bangor, Hereford, and St. Asaph. Davies's Agricultural Report of North Wales, 8vo. Beauties of England and Wales, by Mr. Evans, vol. xvii. Wynne's History of Wales.

Moor-stone

MOOR-*Stone*, the name of a very remarkable stone found in Cornwall, and some other parts of England, and used in the coarser works of the present builders.

This is truly a white granite, and is a very valuable stone. It is very coarse and rude, but has beautiful congeries of variously constructed and differently figured particles, not diffused among, or running into, one another, but each pure and distinct, though firmly cohering with whatever it comes in contact with. Its colours are principally black and white; the white are of a soft, marbly texture, and opaque, formed into large congeries, and emulating a sort of tabulated structure; among these are many of a pure crystalline splendour and transparency; and in some are lodged in different directions many small flaky masses of pure talcs of several colours; some are wholly pellucid, others of an opaque white, others of the colour of brown crystal, and a vast number perfectly black. It is found in immense strata in some parts of Ireland, but is disregarded there.

It is found with us in Devonshire, Cornwall, and some other counties; and brought thence in vast quantities to London. It never forms any whole strata there, but is found on the surface of the earth in immense and unmanageable masses; and to separate these into portable ones, they dig a hole with a wedge in some part of them, and surrounding it with a ridge of clay they fill it up with water; this by degrees soaks in, and finding its way into the imperceptible cracks, so far loosens the cohesions of the particles there, that the day after they drive a larger wedge into the hole, and the stone breaks into two or more pieces. It is used in London for the steps of public buildings; and on other occasions, where great strength and hardness are required.

The people of Cornwall, who have this stone in great plenty, use it in their tin-works, and particularly in their

tin-kiln, on the good effect of which a great deal depends. This kiln is four-square, and at its top is placed a large block or moor-stone; the usual size of this block is six feet in length, and four in breadth. In the middle of this block there is made a hole of about six inches in diameter. This stone serves as a head to cover another like stone placed beneath it; but this under one is not so long as the upper by six inches. The reason of this is, that it must not reach the innermost or back part of the wall, which is the open place through which the flame ascends from another place below that, where a very strong fire of furze is constantly kept up; and there is another little hole also on the outside. The fore-part is like a common oven, and has such a sort of chimney.

The tin-ore is roasted in this kiln, to burn away the mundic, in this manner: the ore is brought in powder, and poured out in heaps on the surface of the top-stone; a man stands there, and thrusts it down through the hole in this stone into the kiln, that is, to the surface of the under-stone: a person who stands below spreads this as it falls with an iron rake, and gives notice to the person above when there is enough down, that is, when the surface of the lower stone is covered three or four inches thick. When this is done, the hole at the top is covered with green turfs, that the flame may reverberate the stronger; and the heat that the moor-stone acquires helps to roast the ore: while the flame that comes up from the ore is blue, there yet remains mundic among it; but when this is burnt off, the flame is yellow. Phil. Transf. N^o 69.

The miners in some parts of Cornwall use the name moor-stone for a sort of coarse free-stone, which lies very often over the tin-ore: this is of a greyish colour, and is somewhat softer than that usually employed in building. See GROWAN.

Mortar

MORTAR, or **MORTER**, in *Architecture*, a composition of lime, sand, &c. mixed up with water : serving as a cement to bind the stones, &c. of a building.

The ancients had a kind of mortar so very hard and binding, that, after so long a duration as to this time, it is next to impossible to separate the parts of some of their buildings ; though there are some who ascribe that excessive strength to time, and the influence of certain properties in the air, which is, indeed, found to harden some bodies very surprisingly.

The lime used in the ancient mortar, is said to have been burnt from the hardest stones, or often from fragments of marble.

De Lorme observes, that the best mortar is that made of pozzolana for sand ; adding, that this penetrates black flint ; and turns them white. See *POZZOLANA*, and *Puteolanus PULVIS*.

Mr. Worledge observes, that fine sand makes weak mortar, and that the larger the sand the stronger the mortar. He therefore advises, that the sand be washed before it is mixed ; and adds, that dirty water weakens the mortar considerably.

Wolfius observes, that the sand should be dry and sharp, so as to prick the hands when rubbed ; yet not earthy, so as to foul the water in which it is washed.

Vitruvius observes, that fossile sands dry sooner than those taken out of rivers. Whence he adds, the latter is fitted for the insides, the former for the outsides of a building. He subjoins, that fossile sand, lying long in the air, becomes earthy. Palladio takes notice, that of all sands white ones are the worst ; and the reason is owing to their want of asperity.

The proportion of lime and sand in our common mortar is extremely variable : Vitruvius prescribes three parts of pit-sand, and two of river-sand, to one of lime ; but the quantity of sand here seems to be too great.

The proportion most commonly used in the mixing of lime and sand is, to a bushel of lime a bushel and a half of sand, *i. e.* two parts of lime and three of sand ; though the common mortar, in and about London, has more sand in it than according to this proportion. The improvement of mortar is certainly an object of great importance : and different schemes have been suggested for giving it that degree of

durability for which the mortar used by the ancients is so justly celebrated.

Mr. Dossie, in the second volume of the *Memoirs of Agriculture*, p. 20, &c. gives the following method of making mortar impenetrable to moisture, acquiring great hardness, and exceedingly durable, similar to that used by the ancients, which was discovered by a gentleman of Neufchatel : take of unslaked lime and of fine sand, in the proportion of one part of the lime to three parts of the sand, as much as a labourer can well manage at once ; and then adding water gradually, mix the whole well together with a trowel, till it be reduced to the consistence of mortar. Apply it immediately, while it is hot, to the purpose, either of mortar, as a cement to brick or stone, or of plaster to the surface of any building. It will then ferment for some days in drier places, and afterwards gradually concrete, or set, and become hard : but in a moist place it will continue soft for three weeks or more ; though it will, at length, attain a firm consistence, even if water have such access to it so as to keep the surface wet the whole time. After this, it will acquire a stone-like hardness, and resist all moisture. The perfection of this mortar depends on the ingredients being thoroughly blended together ; and the mixture being applied immediately after to the place where it is wanted. The lime for this mortar must be made of lime-stone, shells, or marle ; and the stronger it is, the better the mortar will be ; besides, the lime should be carefully kept from the access of air or wet ; otherwise, by attracting moisture, it will lose proportionably that power of acting on the sand, by which the incorporation is produced. It is proper also to exclude the sun and wind from the mortar, for some days after it is applied ; that the drying too fast may not prevent the due continuance of the fermentation, which is necessary for the action of the lime on the sand. When a very great hardness and firmness are required in this mortar, the using of skimmed milk instead of water, either wholly or in part, will produce the desired effect, and render the mortar extremely tenacious and durable.

M. Lorient's mortar, the method of making which was announced by order of his majesty at Paris in 1774, is made in the following manner : take one part of brick-dust finely sifted, two parts of fine river-sand skreened, and as much old slaked lime as may be sufficient to form mortar with

MORTAR

water, in the usual method, but so wet as to serve for the slaking of as much powdered quick-lime as amounts to one-fourth of the whole quantity of brick-dust and sand. When the materials are well mixed, employ the composition quickly, as the least delay may render the application of it imperfect or impossible. Another method of making this composition is to make a mixture of the dry materials; *i. e.* of the sand, brick-dust, and powdered quick-lime, in the prescribed proportion; which mixture may be put in sacks, each containing a quantity sufficient for one or two troughs of mortar. The above-mentioned old slaked lime and water being prepared apart, the mixture is to be made in the manner of plaster, at the instant when it is wanted, and is to be well chafed with the trowel. With respect to this method, Dr. Higgins observes, that M. Lorient corrects the bad quality of the old and effete lime, which constitutes the basis of his mortar, and which has regained a part of the fixed air that had been expelled from it, by the addition of fresh and non-effervescent lime, hastily added to it, at the time of using the composition, which must undoubtedly improve the imperfect mass. And he adds, that when an ignorant artist makes mortar with whiting instead of lime, he can mend it considerably by adding lime to it; but his mortar will still be defective, in comparison with the best that may be made, by reason of the old slaked lime or whiting; this on repeated trials he has found to be the true state of the case. Dr. Higgins has made a variety of experiments, in consequence of the modern discoveries relating to fixed air, for the purpose of improving the mortar used in our buildings. According to this author, the perfection of lime, prepared for the purpose of making mortar, consists chiefly in its being totally deprived of its fixed air. On examining several specimens of the lime commonly used in building, he found that it is seldom or never sufficiently burned; for they all effervesced, and yielded more or less fixed air, on the addition of an acid, and slaked slowly, in comparison with well burned lime. Dr. Higgins also relates some experiments, which shew how very quickly lime imbibes fixed air from the atmosphere; on its exposure to which it by degrees soon loses those characters which chiefly distinguish it from mere limestone or powdered chalk: by soon attracting from thence that very principle, to the absence of which it owes its useful quality as a cement, and which had before been expelled from it in the burning. Hence he concludes, that, as lime owes its excellence to the expulsion of fixed air from it in the burning, it should be used as soon as possible after it is made, and guarded from exposure to the air, as much as possible, before it is used. It is no wonder, therefore, he says, that the London mortar is bad, if the imperfection of it depended solely on the badness of the lime; since the lime employed in it is not only bad when it comes fresh from the kiln, because it is insufficiently burned, and the air has access to it, but becomes worse before it is used, by the distance and mode of its conveyance, and when slaked, is as widely different from good lime, as it is from powdered chalk. For a similar reason, every other cause, which tends to restore to the lime the fixed air, of which it had been deprived in the burning, must deprave it. It must receive this kind of injury, for instance, from the water, so largely used, first in slaking the lime, and afterwards in making it into mortar; if that water contains fixed air, from which few waters are perfectly free, and which will greedily be attracted by the lime. The injury arising from this cause is prevented by the substitution of lime-water, so far as may be practicable or convenient.

From other experiments, made with the view of ascertaining the best relative proportions of lime, sand and water, in

the making of mortar, it appeared that those specimens were the best which contained one part of lime in seven of the sand; for those which contained less lime, and were too short whilst fresh, were more easily cut and broke, and were pervious to water; and those which contained more lime, although they were closer in grain, did not harden so soon, or to so great a degree, even when they escaped cracking by lying in the shade to dry slowly. It appeared farther, that mortar, which is to be used where it must dry quickly, ought to be made as stiff as the purpose will admit, or, with the smallest practicable quantity of water, and that mortar will not crack, although the lime be used in excessive quantity, provided it be made stiffer, or to a thicker consistence than mortar usually is.

Dr. Higgins has also shewn, that though the setting of mortar, as it is called by the workmen, chiefly depends on the exsiccation of it, yet its induration, or its acquiring a stony hardness, is not caused by its drying, as has been supposed, but is principally owing to its absorption of fixed air from the atmosphere, and is promoted in proportion as it acquires this principle; the accession of which is indispensibly necessary to the induration of calcareous cements. In order to the greatest induration of mortar, therefore, it must be suffered to dry gently and set; the exsiccation must be effected by temperate air, and not accelerated by the heat of the sun or fire; it must not be wetted soon after it sets; and afterwards it ought to be protected from wet as much as possible, until it is completely indurated; the entry of acidulous gas must be prevented as much as possible, until the mortar is finally placed and quiescent; and then it must be as freely exposed to the open air as the work will admit, in order to supply acidulous gas, and enable it sooner to sustain the trials to which mortar is exposed in cementitious buildings, and incrustations.

Dr. Higgins has also enquired into the nature of the best sand or gravel for mortar, and into the effects produced by bone-ashes, plaster powder, charcoal, sulphur, &c. and he deduces great advantages from the addition of bone-ashes, in various proportions, according to the nature of the work for which the composition is intended.

This author describes a water-cement or stucco, of his own invention, for incrustations internal and external, exceeding, as he says, Portland stone in hardness, for which he obtained his majesty's letters patent in 1779. As for the materials of which this is made; drift sand, or quarry sand, or, as it is commonly called, pit sand, consisting chiefly of hard quartzose flat-faced grains, with sharp angles, the most free from clay, salts, and calcareous, gypseous, or other grains, less durable than quartz, containing the smallest quantity of pyrites, or heavy metallic matter, inseparable by washing, and admitting the least diminution in bulk by washing, is to be preferred to any other. The sand is to be sifted in streaming clear water, through a sieve which shall give passage to all such grains as do not exceed one sixteenth of an inch in diameter: and the stream of water and sifting are to be so regulated, that all the sand, which is much finer than the Lynn sand, together with clay and other matter, specifically lighter than sand, may be washed away with the stream; whilst the purer and coarser sand, which passes through the sieve, subsides in a convenient receptacle; and whilst the coarse rubbish and shingle remain on the sieve to be rejected. The subsiding sand is then washed in clean streaming water, through a finer sieve, so as to be farther cleansed and sorted into two parcels, a coarser, which will remain in the sieve which is to give passage to such grains of sand only as are less than one thirtieth of an inch in diameter, and which is to be saved apart

under the name of coarse sand; and a finer, which will pass through the sieve and subside in the water, and which is to be saved apart under the name of fine sand. These are to be dried separately, either in the sun, or on a clean iron plate set on a convenient surface, in the manner of a sand heat. Let the lime be chosen, which is stone-lime, which heats the most in slaking, and flakes the quickest when duly watered; which is the freshest made and most closely kept; which dissolves in distilled vinegar with the least effervescence, and leaves the smallest residue insoluble, and in this residue the smallest quantity of clay, gypsum, or martial matter. Let this lime be put in a brass-wired fine sieve, to the quantity of fourteen pounds. Let the lime be flaked by plunging it in a butt, filled with soft water, and raising it out quickly and suffering it to heat and fume, and by repeating this plunging and raising alternately, and agitating the lime, until it be made to pass through the sieve into the water; reject the part of the lime that does not easily pass through the sieve; and use fresh portions of lime, till as many ounces of lime have passed through the sieve as there are quarts of water in the butt. Let the water, thus impregnated, stand in the butt, close covered, until it becomes clear; and, through wooden cocks placed at different heights in the butt, draw off the clear liquor, as fast and as low as the lime subsides, for use. This clear liquor is called the cementing liquor. Let fifty-six pounds of the foresaid chosen lime be flaked, by gradually sprinkling on it, and especially on the unflaked pieces, the cementing liquor, in a close clean place. Let the flaked part be immediately sifted through the fine brass-wired sieve. Let the lime which passes be used instantly, or kept in air-tight vessels, and let the part of the lime which does not pass through the sieve be rejected: the other part is called purified lime. Let bone-ash be prepared in the usual manner by grinding the whitest burnt bones; but let it be sifted to be much finer than the bone-ash commonly sold for making cupels. Having thus prepared the materials, take fifty-six pounds of the coarse sand, and forty-two pounds of the fine sand; mix them on a large plank of hard wood placed horizontally: then spread the sand so that it may stand to the height of six inches, with a flat surface on the plank; wet it with the cementing liquor; to the wetted sand add fourteen pounds of the purified lime, in several successive portions, mixing and beating them up together; then add fourteen pounds of the bone-ash in successive portions, mixing and beating all together. This Dr. Higgins calls the water-cement coarse-grained, which is to be applied in building, pointing, plastering, stuccoing, &c. observing to work it expeditiously in all cases, and in stuccoing to lay it on by sliding the trowel upwards upon it; to well wet the materials used with it, or the ground on which it is laid, with the cementing liquor, at the time of laying it on; and to use the cementing liquor for moistening the cement and facilitating the floating of it.

If a cement of a finer texture be required, take ninety-eight pounds of the fine sand, wet it with the cementing liquor, and mix it with the purified lime and the bone-ash as above, with this difference, that fifteen pounds of lime are to be used instead of fourteen pounds, if the greater part of the sand be as fine as Lynn sand. This is called water-cement fine-grained; and is used in giving the last coating or the finish to any work, intended to imitate the finer grained stones or stucco. For a cheaper and coarser cement, take of coarse sand or shingle fifty-six pounds, of the foregoing coarse sand twenty-eight pounds, and of the finer sand fourteen pounds; and after mixing and wetting these with the cementing liquor, add fourteen pounds, or somewhat less, of the purified lime, and then as much of the

bone-ash, mixing them together. When the cement is required to be white, white sand, white lime, and the whitest bone-ash are to be chosen. Grey sand, and grey bone-ash, formed of half-burnt bones, are to be chosen to make the cement grey; and any other colour is obtained, either by chusing coloured sand, or by the admixture of the necessary quantity of coloured talc in powder, or of coloured vitreous or metallic powders, or other durable colouring ingredients, commonly used in paint. The water-cement above described is applicable to forming artificial stone; by making alternate layers of the cement and of flint, hard stone, or brick, in moulds of the figure of the intended stone; and by exposing the masses so formed to the open air to harden. When it is required for water fences, two-thirds of the bone-ashes are to be omitted, and in its stead an equal measure of powdered terras is to be used. When the cement is required of the finest grain, or in a fluid form, so that it may be applied with a brush, flint powder, or the powder of any quartose or hard earthy substance, may be used in the place of sand, so that the powder shall not be more than six times the weight of the lime, nor less than four times its weight. For inside work, the admixture of hair with the cement is useful. Higgins's Exp. and Obs. on Calcareous Cements, &c. 8vo 1780, passim. See Stucco.

MORTAR, Mixing and Blending of. M. Felibien observes, that the ancient masons were so very scrupulous in this process, that the Greeks kept ten men constantly employed, for a long space of time, to each bason; this rendered the mortar of such prodigious hardness, that Vitruvius tells us the pieces of platter falling off from old walls served to make tables. The same Felibien adds, it is a maxim among old masons to their labourers, that they should dilute with the sweat of their brow, *i. e.* labour it a long time, instead of drowning it with water to have done the sooner.

MORTAR-MILL, in *Rural Economy*, a machine contrived by Mr. Supple, for the purpose of saving labour in the making up of mortar, as well as doing the business more effectually and at a trifling expence. It may also be useful in working clay, &c.

And the mode of doing it is thus described by the inventor: "A pit is dug in the ground, which is bricked at the bottom and sides, into which the operator puts the lime. He has the command of a small stream of water, which is conveyed at pleasure into the pit, and in a few days the lime is sufficiently flaked; he then puts the lime and sand, or gravel, into the mill, which not only mixes both together, but incorporates them in a very effectual manner; and, as the lime is sufficiently moist when taken out of the pit, no more water is required for the mortar. If for present use, the quantity he makes at a time is six bushels, as he finds when more is put in, it is apt to strain the cogs, if not made very strong. If the mortar is made with sand alone, the space between the cogs need not be made so wide as three inches. He has a second shaft, with closer cogs, in order to give the mortar another working; the space between these cogs is but two inches; but it does not answer well till after the first shaft has been used, nor is it necessary, unless for very nice work." He adds, that he "made 200 barrels of lime into mortar last summer, and has now the like quantity of lime in the pit for the same purpose. He made six barrels of mortar in a day with ease; a boy of seven years old drives the horse, and the most indifferent one is good enough for the purpose, the draught being so easy." This machine may be wrought by any other power, as water, wind, or steam.

The nature, plan, and construction of the machine are seen at fig. 4, in *Plate XXIV. Miscellany*, in which A is the plan of

the boarded floor, railed eight inches from the ground, four feet two inches in diameter, and surrounded by a fourteen-inch wall, whose outside height is two feet. B, a sliding door, two feet wide. C, plan of the shaft, with its cogs, or teeth; its length eleven feet eight inches, breadth eight inches, depth five inches. D, plan of the post, or axis, on which the shaft turns round; diameter seven inches, height twenty inches. E E, plan and upright of one of the cogs as it stands in the mill. The plan is a rhombus, the longest diagonal is three inches, the shortest but two, in order to make the angles of the cogs more acute, by which means they will pass through the mortar with the greater ease. F, elevation and section of the mill in perspective.

The inventor states, that the space between the cogs is three inches, except the first to the left of the post, which is but half an inch distant from it, in order to give the cogs to the left a different direction from those on the right; and its use will, by inspection, readily appear. There must be a space of two inches between the end of the cogs and the floor, in order to give the gravel a free passage, which would otherwise strain the cogs, and stop the course of the mill."

Besides the common mortar used in laying of stones, bricks, &c. there are several other kinds: as,

MORTAR. *White*, used in plattering the walls and ceilings; made of ox or cow's hair mixed with lime and water, without any sand. The common method of making this mortar is one bushel of hair to six bushels of lime.

MORTAR *used in making Water-Courses, Cisterns, &c.* is very hard and durable, being made of lime and hogs-grease, sometimes mixed with the juice of figs, and sometimes with liquid pitch; and, after application, is washed over with linseed-oil. See **BETON**.

For this purpose, mortar made of terras, pozzolana, tile-duft, or cinders, is mixed and prepared in the same manner as common mortar: only that these ingredients are mixed with lime, instead of sand, in a due proportion, which is about half and half. The lime should be made of shells or marble; and in works which are sometimes dry and sometimes wet, instead of terras, which is very dear, tile-duft or cinder-duft may be used.

MORTAR *for Furnaces, &c.* See **LUTE**.

MORTAR *for Sun-Dials* on walls may be made of lime and sand, tempered with linseed-oil; or, for want of that, with skimmed milk. This will grow to the hardness of a stone.

For buildings, one part of washed soap-ashes, mixed with another of lime and sand, make a very durable mortar. See **CEMENT**.

The saltpetre workers in France using the mortar of old buildings for extracting that salt, M. Petit has thought it worthy a peculiar attention, and has made several trials, by way of analysis of mortar, to determine whether it really and essentially contains nitre in it, or whether it be only serviceable in that mixture of salts from which nitre is produced.

The common managers of the saltpetre works are of opinion, that mortar contains in it all the saltpetre they procure from it; and that the wood-ashes, and other substances they use with it, only serve to absorb the fat or oily parts, and to set the saltpetre at liberty to shoot. This they pretend to affirm upon experience; but they do not consider, that though they can procure saltpetre from the rubbish or mortar without the addition of wood-ashes, yet it is not pure mortar that they make their experiments upon, but such as is taken from their own heaps, upon which they always throw all the residuum of their former works, and

all that liquor which will shoot no more crystals, but which they call the mother-water of saltpetre.

This gentleman, therefore, very properly judged, that to make a regular trial of the mortar or rubbish alone, he must not take it from their stores, used in the saltpetre works, but pick it himself from the ruins of old buildings.

The mark the saltpetre workers have to know good mortar for their purpose is, that it tastes acrid and salt when applied to the tongue; but to this it may be also added, that it ought to be of a greyish colour, and such as, when powdered and sprinkled upon burning charcoal, yields some sparks of fire; and the more sparks it gives, the better it is for the purpose: and another character of the goodness is, that these well impregnated mortars have a certain unctuousity or fattiness to the touch, which other kinds have not.

The finest of all kinds of mortar for saltpetre work is such as is had from the ruins of old buildings in a low situation, and out of the way of much sunshine; where there has been no great quantity of fire kept, and especially such as has served for the cements of the walls of stables, or the like.

M. Petit chose from such a wall twelve pounds of old mortar: this he had beaten to powder, and poured upon it eighteen pints of water; the whole was then set over the fire, and stirred from time to time for three or four hours, that the water might be well tinctured from the mortar; after this the water was filtered through paper, and was then found to be tinctured to a pale, yellow, transparent bitter, and somewhat acrid to the taste.

The impregnation may be made without heat, by only stirring the mortar about for nine or ten days in cold water, and a quantity of the salt taken up will be according to the goodness of the mortar and the quantity of water employed. The common specific gravity of this liquor to water is as 32 to 31, or thereabouts. M. Petit having procured the tincture of fifty pounds of mortar, by several impregnations, in 72 French pints of water, evaporated it so far till it appeared highly charged with saline particles, tasting very acrid and bitter, and being of a brownish-red colour; and its specific gravity was in this state to water as 4 to 3, there being more in quantity than about four pints. This was still limpid and of a dusky colour, and was afterwards evaporated over a gentle fire, to the consistence of an extract, which, as it cooled, became much thicker and firmer, resembling butter. This being left open to the air, soon relented into a liquor of the consistence of a syrup: its specific gravity was now to water as 5 to 3; but in leaving it open to the air, it continually attracted fresh humidity, and became less specifically heavy. Experiments made with this extract succeeded in the following manner:

1. It turned the common blue paper to a fine deep red. The impregnations in water unspissated do this also in different degrees, according to their strength.

2. Mixed in equal quantities with spirit of nitre and with spirit of sea-salt, it made no effervescence or alteration in either.

3. A leaf of gold being put into the mixture of this impregnation with spirit of nitre, was immediately dissolved; and in an hour or two afterwards, the liquor was much clearer than before.

A leaf of gold being put into the mixture of this impregnation and spirit of sea-salt, was in the same manner dissolved in a few minutes. It is generally supposed, indeed, that the spirit of salt alone will dissolve gold; but there seems to be an error in this, founded on the inaccuracy of the preparation of such spirit of salt; for Messrs. Geoffroy and Boulduc

have at different times produced before the French Academy spirit of salt carefully prepared by themselves, which would not at all dissolve gold, not even with the assistance of heat : even such spirit of salt would, however, be made to dissolve gold, by mixing this impregnation with it ; so that it has the power of dissolving gold in a great degree.

4. A leaf of silver being dissolved in spirit of nitre, and this impregnation of mortar added to the solution, the whole became turbid, and a precipitation happened, part of the matter being thrown to the bottom, and part remaining suspended in form of a white cloud, which kept its place without falling.

5. The impregnation being mixed in equal quantities with oil of vitriol formed a coagulum, and made a great effervescence, with copious red vapours, and a strong smell of aqua fortis ; and these vapours appeared at any time, on stirring the mixture, for several days together. If a larger quantity of oil of vitriol be added to this coagulum, it all becomes fluid, but ferments violently ; and finally, there will be a white matter precipitated to the bottom of the clear liquor ; and if a leaf of gold be brought near this mixture, it will be dissolved even by the vapour which exhales from it. Spirit of nitre has no effect upon this mixture, either in its state of coagulum, or when reduced by more oil of vitriol into a clear liquor ; but the volatile spirit of urine ferments violently, without the least heat with it.

6. Oil of tartar *per deliquium* being added to the impregnation, the liquors would not readily mix, but remained separate, the impregnation sinking to the bottom ; but on stirring them thoroughly together, they finally were made to unite into a white substance like butter, with a strong urinous smell. If a small quantity of corrosive sublimate be added to this mixture, the urinous smell ceases ; and if oil of vitriol be added, there is a violent fermentation occasioned ; and, in fine, a large quantity of precipitate.

7. This impregnation of mortar being mixed with an equal quantity of a solution of corrosive sublimate, there is nothing remarkable produced, though the mixture be ever so much shaken ; but if a little oil of tartar *per deliquium* be added to this, the mixture becomes turbid, and, on stirring all together for some time, it becomes white and thick like butter. If to this, more corrosive sublimate be added in solution, it becomes orange-coloured : and, on more stirring, this becomes again white ; and finally gives a white precipitate at the bottom of a transparent liquor.

8. If, instead of oil of tartar, an equal quantity of lime-water be added, this in the same manner gives an urinous

smell, and the whole difference is, that the mixture will not become thick with this, as it will with oil of tartar.

9. The impregnation of mortar produced the same coagulum in mixing with spirit of urine, that it did with oil of tartar *per deliquium* ; but it made no coagulation with spirit of sal ammoniac with lime : the occasion of this difference is, that the spirit of urine contains a great deal of volatile salt, and the other but little. It is a common error to suppose that the spirit of sal ammoniac, which is most pungent, contains the greatest quantity of salt ; but this is not the case, for the spirit made with lime is much more pungent than that with salt of tartar, though the last is well known to contain a much larger portion of saline particles.

10. If a piece of paper or linen be wetted in this impregnation, and afterwards dried, it takes fire very violently, and sparkles with the same violence as if it was impregnated with saltpetre.

From these experiments it is abundantly proved, that the impregnation of mortar contains a large quantity of a saline and nitrous ammoniac salt ; for a dissolution of sal ammoniac and spirit of nitre, mixed together, are found to produce all the changes in the different bodies before named, that the impregnation does. On the whole, though it has been supposed by Mr. Tournefort, and others, that mortar contained saltpetre, sea-salt, and a fixed alkali ; yet there does not appear any proof of its containing any of these salts : no fixed alkali can ever be separated from the impregnation of it ; and though the linen or paper, wetted in the impregnation of it, sparkled when on fire, yet it is not nitre, but merely a nitrous sal ammoniac, which occasions that phenomenon. The same effect is produced, if the linen or paper be wetted with a mixture of spirit of urine and spirit of nitre. And the several experiments before recited prove, that there is in mortar a spirit of nitre and a spirit of sea-salt, which, with the volatile urinous salts, form a nitrous or a saline ammoniac. Mem. Acad. Scienc. Par. 1734.

MORTAR, in *Chemistry*, &c. is an instrument very useful for the division of bodies, partly by percussion, and partly by grinding. They have the form of an inverted bell, and are made of all sizes and materials, as marble, copper, glass, iron, grit-stone, and agate. The matter intended to be pounded is to be put into them, and there struck and bruised by a long instrument called a *pestle*. This, when large and heavy, ought to be suspended by a cord, or chain, fixed to a moveable pole, placed horizontally above the mortar, which considerably relieves the operator, because its elasticity assists the raising of the pestle.

Mould

MOULD, or MOLD, in the *Mechanic Arts*, &c. a cavity artfully cut, with design to give its form, or impression, to some softer matter applied in it.

Moulds are implements of great use in sculpture, foundery, &c.

The workmen employed in melting the mineral or metallic glebe dug out of mines, have each their several moulds, to receive the melted metal as it comes out of the furnace ; but these are different, according to the diversity of metals and works. In gold mines, they have moulds for ingots ; in fil-

ver mines, for bars ; in copper and lead mines, for pigs or salmons ; in tin mines, for pigs and ingots ; and in iron mines, for sows, chimney-backs, anvils, cauldrons, pots, and other large utensils and merchandizes of iron ; which are here cast, as it were at first hand.

MOULDS of *Founders of large Works*, as statues, bells, guns, and other brazen works, are of wax, supported within-side by what they call a *core*, and covered withoutside with a cap or case. It is in the space which the wax took up, which is afterwards melted away to leave it free, that the liquid

metal runs, and the work is formed; being carried thither through a great number of little canals, which cover the whole mould. See **FOUNDERY**.

MOULDS of Moneyers are frames full of sand, in which the plates of metal are cast that are to serve for the striking of species of gold and silver. See **COINING**.

A sort of concave moulds made of clay, having within them the figures and inscriptions of ancient Roman coins, are found in many parts of England, and supposed to have been used for the casting of money.

Mr. Baker having been favoured with a sight of some of these moulds found in Shropshire, bearing the same types and inscriptions with some of the Roman coins, gave an account of them to the Royal Society.

They were found in digging of sand, at a place called Ryton, in Shropshire, about a mile from the great Watling-street road. They are all of the size of the Roman denarius, and of a little more than the thickness of a halfpenny. They are made of a smooth pot or brick clay, which seems to have been first well cleansed from dirt and sand, and well beat or kneaded, to render it fit for taking a fair impression. There were a great many of them found together, and there are many of them not unfrequently found in Yorkshire; but they do not seem to have been met with in any other kingdom, except that some have been said to be once found at Lyons. They have been sometimes found in great numbers, joined together side by side, on one flat piece of clay, as if intended for the casting a great number of coins at once; and both these, and all the others that have been found, seem to have been of the emperor Severus. They are sometimes found impressed on both sides; and some have the head of Severus on one side, and some well-known reverse of his on the other. They seem plainly to have been intended for the coining of money, though it is not easy to say in what manner they can have been employed to that purpose, especially those which have impressions on both sides, unless it may be supposed that they coined two pieces at the same time by the help of three moulds, of which this was to be the middle one.

If by disposing these into some sort of iron frame or case, as our letter-founders do the brass moulds for casting their types, the melted metal could be easily poured into them, it would certainly be a very easy method of coining; as such moulds require little time or expence to make, and therefore might be supplied with new ones as often as they happen to break.

These moulds seem to have been burnt or baked sufficiently to make them hard; but not so as to render them porous like our bricks, by which they would have lost their smooth and even surface, which in these is plainly so close, that whatever metal should be formed in them would have no appearance like the sand-holes by which the counterfeit coins and medals are usually detected.

MOULDS of Founders of small Works are like the frames of coiners: it is in these frames, which are likewise filled with sand, that their several works are fashioned; into which, when the two frames of which the mould is composed are rejoined, the melted brass is run.

MOULDS of Letter-founders are partly of steel and partly wood: the wood, properly speaking, serves only to cover the real mould which is within, and to prevent the workman, who holds it in his hand, from being incommoded by the heat of the melted metal. Only one letter or type can be formed at once in each mould. See **Letter-FOUNDERY**.

MOULDS, in the *Manufacture of Paper*, are little frames composed of several brass or iron wires, fastened together by

another wire still finer. Each mould is of the bigness of the sheet of paper to be made, and has a rim or ledge of wood to which the wires are fastened. These moulds are more usually called *frames* or *forms*.

MOULDS, Furnace and Crucible Makers', are made of wood, of the same form with the crucibles; that is, in form of a truncated cone: they have handles of wood to hold and turn them with, when, being covered with the earth, the workman has a mind to round or flatten his vessel.

MOULDS for Lead Bullets are little iron pincers, each of whose branches terminates in a hemispherical concave, which, when shut, form an entire sphere. In the lips or sides, where the branches meet, is a little jet or hole, through which the melted lead is conveyed.

MOULDS, Laboratory, are made of wood, for filling and driving all sorts of rockets and cartridges, &c.

MOULDS, Glaziers'. The glaziers have two kinds of moulds, both serving to cast their lead: in one they cast the lead into long rods or canes fit to be drawn through the vice, and the grooves formed therein; this they sometimes call *ingot-mould*. In the other they mould those little pieces of lead a line thick, and two lines broad, fastened to the iron bars. These may be also cast in the vice.

MOULDS, Goldsmiths'. The goldsmiths use the bones of the cuttle-fish to make moulds for their small works; which they do by pressing the pattern between two bones, and leaving a jet or hole to convey the silver through, after the pattern has been taken out.

MOULD, among *Masons*, is a piece of hard wood or iron, hollowed within, answerable to the contours of the mouldings or cornices, &c. to be formed. This is otherwise called *caliber*.

MOULD, a cavity formed in the external surface of a body, intended to be cast of liquid or soft matter, which after a certain time will acquire solidity.

MOULD, in *Masonry*, is a templet made to a section of the stone intended to be cut. The ends or heading-joints being formed as in a cornice by means of the mould, the intermediate parts are wrought down by straight edges or circular templates, according as the work is straight or circular, upon the place. When the surface intended to be made is required to be very exact, a reverse mould is used in order to prove the work, by applying the mould in a transverse direction.

MOULDS, among *Plumbers*, are the tables on which they cast their sheets of lead. These they sometimes call simply *tables*. Besides these they have other real moulds, with which they cast pipes without folding. See each described under **PLUMBERY**.

MOULDS, among the *Glass-Grinders*, are wooden frames, on which they make the tubes with which they fit their perspectives, telescopes, and other optic machines.

These moulds are cylinders, of a length and diameter according to the use they are to be applied to, but always thicker at one end than the other, to facilitate the sliding. The tubes made on these moulds are of two kinds; the one simply of pasteboard and paper; the other of thin leaves of wood joined to the pasteboard. To make these tubes to draw out, only the last or innermost is formed on the mould; each tube made afterwards serving as a mould to that which is to go over it, but without taking out the mould from the first. See **GRINDING**.

MOULDS used in basket-making are very simple, consisting ordinarily of a willow or osier turned or bent into an oval, circle, square, or other figure, according to the baskets, panniers, hampers, and other utensils intended. On these moulds they make, or, more properly, measure, all their

work : and, accordingly, they have them of all sizes, shapes, &c.

MOULDS, in *Ship Building*, are the shapes of the various timbers, knees, &c. made of board from the lines on the mould-loft floor, for the purpose of sawing out the various timbers, &c. to the shape required. Also thin flexible pieces of pear-tree or box, used in drawing the draughts and plans of a ship.

MOULD-*Loft* is a long even floor, on which the ship is laid-off to its full size, from the draughts and several other operations, which will be correctly explained in the article SHIP-BUILDING.

MOULDS, among *Tallow Chandlers*, are of two kinds : the first for the common dipped candles, being the vessel in which the melted tallow is disposed, and the wick dipped.

This is of wood, of a triangular form, and supported on one of its angles, so that it has an opening of near a foot

at top : the other, used in the fabric of mould candles, is of brass, pewter, or tin. Here each candle has its several mould. See each under CANDLE.

MOULD, among *Gold Beaters*, a certain number of leaves of vellum, or pieces of guts, cut square, of a certain size, and laid over one another, between which they put the leaves of gold and silver which they beat on the marble with the hammer. See GOLD-Leaf.

They have four kinds of moulds ; two of which are of vellum, and two of gut : the smallest of those of vellum consists of forty or fifty leaves ; the largest contains a hundred : for the others, each contain five hundred leaves.

The moulds have all their several cases, consisting of two pieces of parchment, serving to keep the leaves of the mould in their place, and prevent their being disordered in beating.

Muffle

MUFFLE, in *Metallurgy*, is an arched cover, resisting the strongest fire, and made to be placed over copels and tests in the operation of assaying, to preserve them from the falling of coals or ashes into them; though at the same time of such a form, as not to hinder the action of the air and fire on the metal, nor prevent the inspection of the assayer.

The muffles may be made of any form, so that they have these conditions; but those used with copels are commonly made semi-cylindrical, or when greater vessels are employed, in form of a hollow hemisphere.

The muffle must have apertures, that the assayer may look in, and the fore-part of it must always be quite open, that the air may act better in conjunction with the fire, and be incessantly renewed; for without this, scarcely any fumes are to be produced, and without these, the vitrification of lead is scarcely practicable; for when the air is once filled with a certain quantity of vapours, it scarcely admits any more afterwards; and for this reason a constant succession of fresh air is necessary. The apertures in the muffle serve also for the regimen of the fire; for the cold air rushing into the larger opening before, cools the bodies in the vessel; but if some coals are put in it and its aperture before be then shut with a door fixed to it, the fire will be increased to the highest degree, much more quickly than it can be by the breathing-holes of the furnace. Another use of these apertures is also, that the arsenical vapours of lead and antimony, passing through the holes in the back part of the muffle, may not be offensive to the assayer, who stands before it.

As to the height, length, and depth of the muffles, these must be proportioned to the size and number of the vessels they are intended to cover; and care must be taken in this, that all parts of the inner surface of those vessels must be within the reach of the assayer's eye. The most frequent size of the muffle, however, is four inches high, six or eight inches long, and four or six inches broad. The segments cut off at the bases, for the lesser holes, must be of such a proportioned height, that the least vessels put under it, may

not be in the way of coals or ashes falling into them, for that always hinders the vitrification of lead, and the destruction of the other metals and semi-metals, and will sometimes entirely reduce them again when already destroyed; and the scorix, softened by ashes, soften and retard the operation.

Wooden moulds of a proper shape are most convenient for the making of these muffles, and the matter of which they are made is the same with that of the German clay-tests; this is, either a pure native clay, of a condition to bear the fire, which will be known upon the trial; or such clay hardened by a mixture of the powder of stones: and in order to the forming of these, the mass must be made tolerably soft and pliant. Knead a sufficient quantity of this mass with your hands upon a flat stone; spread it out evenly into a thin cake or plate, somewhat longer and broader than you intend the muffle to be made; and so thick, that two or more thin plates or lamina, of about two lines thick each, may be cut off from it. This is easily done by rolling the mass on the stone with a rolling-pin, strewed over lightly with ashes, or powder of chalk.

When the cake is thus rolled out, with a thin, fine, and perfectly straight brass-wire, cut off from the cake one thin plate; this must be done with great caution lest it should break: take this up, and rubbing it over with oil or fat, lay it over the mould; then cut out a semicircular piece from the mass, of the same thickness with the former, and with this cover the back plane, or farther end of the mould, joining the edges of this plate to those of the former, closely and perfectly, by wetting them well with water.

Next cut off from the cake another thin plate, to be the bottom of the muffle; this may be either left loose for the muffle to be placed on it occasionally, or the bottom edges of the already formed muffle may be joined to it all round by means of water, as the back was before jointed to the arched part of the muffle. But whether it be intended that the bottom should be thus fixed on, or left loose, it must

be half an inch broader every way than the bottom of the muffle, that this may stand the more sure and firm upon its basis.

When the muffle is thus made, wet your hand, and rub it carefully all over, that the small, and perhaps invisible, cracks and chinks in the plates may be closely joined, and the whole matter of it applied perfectly close to the surface of the mould.

When the muffle has been some time exposed to the air, and is somewhat dried, and hardened on the mould, cut out two or three hemispherical pieces on each side, to make the holes before described, at the basis and back, and then draw away the mould from within it; for if the muffle is suffered to dry perfectly on the mould, it always cracks. When the whole is perfectly dry, let it be baked in a potter's kiln, or in the assayer's oven; but without great care in the latter method, and lighting the fire at top at first, it is apt to crack; so that the potter's kiln, where at hand, is much the better way of baking it.

If there be adapted to the formerly described convex mould, another concave one nearly fitting it, only leaving room for the thickness of the muffle between them, and the clay be placed between them, and formed by this means into its exact shape, by a strong and every way equal pres-

sure, this will make muffles not only with much less trouble, but they will be much stronger, less apt to crack, and more capable of resisting the fire, than those made by the hand in the other way.

The only cautions necessary for making these, are, that the clay be a little drier than when it is to be worked by the hand; that the sides, both of the inner and convex mould, and of the outer concave one, be thoroughly oiled or greased, and the pressure on the surface of the outer or concave mould be as strong and equal as may be. There is no clay better for making these muffles than the Windsor-loam, an earth well known among the chemists and glassmen, and always to be sold in London; and rubbing the inside of the mould with black lead in fine powder very well supplies the place of greasing them, to prevent the matter from sticking to them.

These are the muffles ordinarily used in assaying; but when very large tests are to be covered, they use large spheroidal muffles, made of cast iron, or sometimes of the same clay, and wrought in the same manner, only made upon proportionably larger moulds. The clay is usually, for these large ones, only laid in a lump on the top of the mould, and with wet hands spread all over it to the bottom, and by this means a muffle is made with little trouble. Cramer.

Nails

NAILS, in *Building*, &c. are little metalline members, serving to bind or fasten the parts together, &c.

The several kinds of nails are very numerous. As *back* nails, made with flat shanks to hold fast, and not open the wood. *Clamp* nails, those proper to fasten the clamps in buildings, &c. *Clasp* nails, whose heads are flattened, and clasping and sticking into the wood, render the work smooth, so as to admit a plane over it: the most common in building are distinguished by 1*od.*, 2*od.*, 2*s.*, &c. *Clench* nails, those used by boat, barge, &c. builders, with bolts or nuts, and often without: for fire work, they are made with clasp heads, or with the head beat flat on two sides. *Clout* nails, those ordinarily used for nailing on of clouts to axle-trees; they are flat-headed nails, and iron work is usually fixed with these nails. *Deck* nails, those proper for fastening of decks in ships, doubling of shipping, and floors laid with planks. *Dog* nails, or *j bent* nails, proper for fastening of hinges to doors, &c. *Flat* points are of two kinds, *viz.* *long*, much used in shipping, and proper where there is occasion to draw and hold fast, yet no necessity of *clenching*; and *short*, which are fortified with points, to drive into oak, or other hard wood. *Lead* nails, used to nail lead, leather, and canvas, to hard wood: these are *clout* nails dipped in lead or solder. *Port* nails, commonly used to nail hinges to the ports of ships. *Ribbing* nails, used to fasten the ribbing, to keep the ribs of ships in their place in building. *Rose* nails are drawn four-square in the shank, and commonly in a round tool. *Rother* nails, chiefly used to fasten rother-irons to ships. *Scupper* nails, much used to fasten leather and canvas to wood. *Sharp* nails, much used, especially in the West Indies, made with sharp points and flat shanks. *Sheathing* nails, used to fasten sheathing-boards to ships: the rule for their length is, to have them full three times as long as the board is thick. *Square* nails, of the same shape as *sharp* nails; chiefly used for hard woods. *Brads*, long and slender, without heads, chiefly used for thin deal work, to prevent splitting. To which may be added *tacks*; the smallest serving to fasten paper to wood; middling, for wool-cards and oars; and larger, for upholsterers and pumps. They are distinguished by the names of *white tacks*, 2*d.*, 3*d.*, and 4*d. tacks*.

Nails are said to be toughened, when too brittle, by heating them in a fire-shovel, and putting some tallow or

grease among them.

Nails are sold six-score to the hundred.

NAILS, *Manufacture of*. The immense consumption of these articles, in all the mechanic arts and trades, cause their fabrication to be a considerable branch of national manufacture. It is chiefly carried on in Staffordshire, in the neighbourhood of Dudley, Wolverhampton, and Birmingham: indeed it is the principal consumption of the malleable iron made in that part of England. The iron used in the nail trade is of the cheapest sort, chiefly made in the Pudding furnaces, and worked by rollers instead of a forge-hammer. (See IRON.) This metal is, by repeated rolling, reduced into small thin bars, which are then passed through the grooves of the flitting-rollers, and thus divided or slit into three, four, five, or six small square rods, of a proper size to make nails. (See ROLLING-MILL) These, which are called nail rods, are a very extensive article of trade. The nailers reside chiefly in the cottages, where the women and children assist in the labour. They employ forges such as are used by smiths; but the bellows are very lightly loaded, so that a very small motion given to them now and then will blow sufficiently to heat the rods; two, three, or four of which, according to their size, are always kept in the fire together: and when any one has a good red heat, the nailer takes it out of the fire, and, battering it on the anvil, brings it to a sharp square point at two or four strokes; he then applies it over the edge of a chisel, fixed on the anvil, and by striking a single blow on the rod, cuts off a sufficient length to make a nail, which falls into a tin pan; then he makes another, and cutting it off likewise, returns the end of the rod to the fire for another heat: now, with a pair of tweezers, like sugar-tongs, he takes up the nail, and introduces its point into a square tapering hole, made across through the end of an iron tool or mould; by striking a blow or two on the end of the iron, he flattens it down, and forms a head, the figure of which is determined by the number and direction of the blows given it. This process is conducted with a surprising rapidity, as the nailers, by long practice, acquire a mechanical habit of forming a complete nail by a certain number of strokes, so as never in the course of an hour to make an unnecessary movement. For large nails they can only make one, and cut it off, at each time they take the iron from the fire; because they would be un-

able to get the heading finished, whilst they were sufficiently hot. The length of the nail is regulated by a stop, fixed at a certain distance from the edge of the chisel, so that the point of the nail being applied to this, determines the proper place for the edge of the chisel. The size of the mould within, and the dimensions to which the point of the nail is reduced by hammering, causes the cut end to project above the surface of the mould more or less; so that the head will be thicker or thinner, and have its quantity of metal regulated, by the degree of taper given to the point: therefore, the art of the workman is displayed in striking with a due force, so that every nail shall be made of the same size, by a certain number of blows. In this manner the great number of all nails are made; but the great expence of labour has induced many manufacturers to turn their attention to inventions which would diminish the labour, so as to enable them to bring their nails to the market at reduced prices, or of a better quality. Many patents have been taken out for these inventions, some of which we shall briefly notice.

Mr. W. Finch of Wimborne, in Staffordshire, obtained a patent in 1790, for manufacturing nails by machinery. He proposed, by means of a water or steam-mill giving motion to a main shaft or axis, to actuate a number of small hammers, to work either in a tilt or lift manner. By these hammers the nails were to be forged; but the operation was to be divided among three people for headed nails: thus, one to attend the fire, and carry the rods, as fast as they were properly heated, to the second person, stationed before the hammer, who would make the nails in the most expeditious manner, by only turning the rod about under the hammer; when cut off, they were taken by the third person, who finished the heads in a tool as above described, but by means of a hammer worked by machinery, instead of hard labour. By these contrivances, in consequence of the more speedy motion of the machine hammers, several nails were to be made at once heating of the rod; whereas by the old method, only one, or two at most, could be made; thus making a great saving of labour: and as the operation required no strength, children might easily make the largest spikes; the motion of the hammer being so regular, that they could easily acquire a dexterity in turning the rods properly to receive the blows.

In the year 1790, Mr. Thomas Clifford, of the city of Bristol, obtained two patents for the manufacture of nails of every kind. The principle on which his first invention was founded, was that of making the nails in a die, that is, by having a die, or the impression of the nails to be cut, formed in one or more pieces of steel; and the iron, of which the nails are to be formed, is drawn or rolled into the proper form or thickness, and, by a force adapted to the purpose, pressed into a cavity or die, so as to form the nails either complete, or so nearly complete, as that they can be finished with very little labour. This operation may be done in several ways, but the one particularly recommended by Mr. Clifford is by rollers of iron or steel, and worked either by water, steam, wind, horses, &c.

The two rollers are to be made of iron, and cased with steel, each of the same diameter, which is proportioned to the length and size of the nail intended to be made. Each roller should have a cog-wheel on it, the cogs of one roller to work into those of the other, so that both the rollers may perform the same exact revolution. One half the impression of the nail is to be cut in the surface of one roller, the other half in the other, so that the two impressions form a cavity or die of the exact form of a nail, extending the lengthways of the nail on the circumference of the rollers; and as

many impressions of the same kind may be cut in the rollers, one at the end of the other, as will complete their circumference, and continue the cavity all round the rollers; the point of one nail joining the head of the next, or the two points and two heads joining each other. The rollers must, in this as in other cases, be made to work very true and close to each other.

The mode of operation is this: a rod of iron, previously rolled or drawn to a convenient size, is to be heated, and, while hot, the end of it is put between the rollers into the cavity or die which forms the impression of the nail. The rollers, being now put in motion, will draw the iron through, and pressing it into the cavities or dies, forms the iron into nails, one joined to the other, which must afterwards be separated, by means of instruments acting as nippers, shears, chisels, &c. The rollers, being made to work very close to each other where the edge of the nail is formed, will prevent much of the metal from being pressed out on each side of the nail, and what is pressed out may be cut off by instruments adapted to the purpose. Several pairs of rollers may be made to work together, and each pair may have several rows of dies cut on them, so as to form the impression for several strings of nails; and a rod of iron being put into each of them, will roll out as many strings of nails with one revolution of the rollers. A pair of rollers may also have the greater part of their surface cut with dies, and a flat bed made to pass between the rollers so as to form sheet nails; all of them connected to one another by thin plates of the iron of which they are composed; and this would require each nail to be cut out, or separated from the sheet by proper instruments.

Mr. Clifford's second invention consists, 1st, in drawing the iron or other metal into a tapering or wedge-like form, according to the length and thickness of the different sizes of nails to be made. 2dly. The nails are to be cut out of those wedge-like or tapering plates by means of a punch, the face of which is made according to the size, taper, and form of the nail to be cut out; as also having a hollow bolster, the hollow or aperture of which must also be made of the size and form of a nail, and consequently to fit and receive the punch above-mentioned. The punch, thus fitted to the bed, and sliding in a proper frame to keep it steady, will, by a blow, or by pressure, cut or force part of the taper plate into and through the aperture of the bed fitting to it, and by which the nail is formed. This operation is by the manufacturers of buckles, buttons, &c. called cutting out. 3dly. To form the heads of horse nails called rose heads, and others of nearly a similar kind: after the operations of drawing and cutting out, the nail is to be put into a heading tool, also called a bed, which bed receives the nail, excepting a small portion at the thick end, out of which the head is formed by a punch or die. This die, by blow or pressure, forms the head as required, and when the nails are made of hard iron, after they are cut in the way described, the thick end is made hot before they are put into the bed, or heading tool. 4thly. Another method adopted in the manufacture of nails is, by cutting them out of or from plates of equal thickness, and afterwards to point them either by hammer or other pressure. 5thly. In making nails that are of a triangular form, the plate or strip of iron is pressed or stamped into a die, having impressions cut to the form of such nails, after which they are cut out by a punch.

About 15 years ago, a very extensive trade was established in Birmingham and Sheffield of cut brads: that kind of nails called brads having no head, or at least only a small projecting leaf on one side, was easily cut out by machinery, without the trouble of forging, but latterly the method has been

improved, so far as to produce all kinds of small nails. The iron is rolled out to large thin sheets, of the proper thickness to form a nail; this is cut up by strong shears into parallel slips or ribbands, the width of them being equal to the length of the intended nails, which are cut off, one at a time, from the end of the slip: the cutting line is not exactly perpendicular to the length of the piece, but rather inclined, so as to make the nail, which is cut off sharp at one end; the next time the cutting line is inclined the other way, so that the head of one nail is cut from the same edge of the slip as the point of the next, and so on alternately. The cutting is performed by the *fly-press* (see that article), proper dies or cutters being applied in it: the lower or fixed die consists of a cutter or bar of steel set up edgewise, and one of the angles of its upper side is ground to a sharp straight edge. The slider of the press carries a die, consisting of a square bar of steel moving perpendicularly by the action of the screw, and when it is forced down, one of its flat sides applies exactly against the straight edge of the fixed cutter above-mentioned; but when the moving cutter is raised up to the highest, a part is observed, where its flat side is cut away, in such a manner as to leave a considerable space between its face and the edge of the fixed cutter at one end of the edge, but touching it at the other. By this means, when the end of a slip of iron is pressed against the face of the moving cutter in its reduced part, a short piece of the end of the slip will project over the edge of the fixed cutter, and the moving cutter being forced down by the screw of the press, the shoulder of the part which is cut away comes down upon the end of the slip, cutting it off to the line of the edge of the fixed cutter, and therefore removing a small piece from the end, which being of a proper breadth at one end, and regularly tapered away to nothing at the other, makes a very good brad. The circumstance of its being parallel in the other direction, is the great recommendation to this kind of nail, because it will drive without first making any hole in the wood and does not split: the point of a nail of this kind is like the edge of a chisel, and the length of this edge being set across the grain of the wood, when driven down it cuts through, and divides all the fibres of the wood it meets with, and by turning the divided ends of them down, as it is driven deeper, their elasticity binds the nail forcibly between them, so that this nail will hold in the wood faster than any other kind, but being parallel in the other direction, does not tend to open or split the wood in the direction of the grain.

In cutting brads by this method, the workman or woman is seated before the press, which is the same as is shewn in *fig. 1. Plate XXVII. Mechanics*, holding the handle, *a*, of its fly in the right hand, and the slip of iron in the left: by pushing the handle back, the moving cutter is raised up, and the end of the slip is pressed up to the cutter: then by drawing forwards the handle, the cutter is pressed down, carrying with it a nail, as before mentioned: the handle is then pushed back to cut another, but the slip of iron or bar must first be turned over, to bring the other side upwards: by this means, the bar will at the second time be cut with an inclination in an opposite direction to what it was the first time, so that the head of one nail will come from the same side of the bar as the point of the last, and this alternately of the whole. A woman will, by this method, cut small nails at the rate of 40 or 50 *per* minute, and if they are intended for brads, they have a small leaf left at one side of the head in cutting, by a particular shape of the dies.

For nails which require heading, the pieces or nails, cut as before mentioned, are taken to another woman, who fixes them one at a time in a vice, over which a heavy hammer is placed, being fitted on an axis, that it may rise and fall with

precision upon the head of the nail in the vice; its weight is suspended by a wooden spring pole, and the woman, when she has fixed the nail, raises the head of the hammer a little, and then brings it sharply down on the nail, so as to head it at one blow. The shape of the head is determined by an indentation made in the face of the hammer, and its thickness depends upon the quantity which is left sticking out above the chaps of the vice.

Messrs. Wilmore and Tonk obtained a patent, in 1808, for a method of cutting nails, which they have thus described.

They take a nail rod, of a size suitable to that of the nail intended to be manufactured, and applying it to a common screw-press, mounted with proper cutters, cut off from the end of the rod two pieces at once, obliquely across the rod in one place, and directly across it in another. Two studs or tops are set up, which are attached to the press, and are moveable in the direction of the rod, for the purpose of ascertaining the length of the nail; and both studs are adjustable in the cross direction of the rod, so that the obliquity of the cut, according to the kind of nail to be made, is thereby determined, as well as the length of the nail. This is called the first operation.

The second operation is to anneal the pieces so cut off, if the iron should not be sufficiently malleable, which is done in the usual and well-known manner. The third operation is that of heading, which, for clasp head nails, consists of two parts, one for gathering, and the other for forming the head of the nail. The first part of this operation is performed by putting a piece, cut off the rod of iron as before described, into a pair of clams, leaving as much of the thick end projecting above the clams as is sufficient to form the head. These clams have steel bits let into them with sharp edges, which press only against the two opposite sides of the piece, and which have the effect of two chisels, when the punch of the press is brought down upon the piece with considerable force, and raise or gather up iron towards forming the head. The second part of this operation is to put the nail, thus prepared, into another pair of clams, having bits to correspond to the under side of the head; and the punch, having the impression of the upper side of the head engraved or sunk into it, is brought to press strongly upon the head in the clams, and thereby the clasp head is properly formed.

For nails intended to have rose heads, or any other kind of heads, except clasp heads, the first part of this heading operation is not absolutely necessary, but the bits which for clasp nails must have sharp edges, must for the other nails have blunt edges, to prevent the under-cutting. For the second part of this operation, the piece is put either into a pair of clams, or into the tool commonly called a bore, and then pressed with punches properly engraved, or sunk, according to the kind of head wanted. By the first of all these operations, the piece cut off the rod of iron is formed something like a mortise chisel. The fourth operation is to point it, which is done by putting the piece into a bed of steel, in which is cut a nick or groove having parallel sides, but the bottom rising towards the end, where the nail is to be formed; the end of the punch, which presses upon the point of the nail, is made to project more than the other part, so as to meet the corresponding part of the bed, when the punch is brought upon the nail. The groove or nick in the bed should be just wide enough to receive the nail easily, but prevent it from twisting when the impression is made. The nail is put twice into the nick, once within the chisel, from the end lying horizontal, and next turning a quarter round to press the chisel edge into a pointed form. If the nails, by the strong pressure which is necessary in this opera-

tion, should become too hard to clench, they are to be annealed in the usual way, which may be called the fifth operation. The third, fourth, and fifth operations, above described, are applied to nails, or pieces cut off from sheet or rolled iron in the ordinary way; but as, in consequence of the fifth operation, which is necessary to give them the quality of clenching, they are apt to be too soft to drive well, a sixth operation is applied, *viz.* quenching them in water when red-hot, which gives them stiffness enough to drive without rendering them too brittle to clench.

The Americans appear to have carried the invention of cutting nails by machinery to a greater perfection than has been done in this country. From some letters, published in 1810, by the American secretary to the treasury, in his report on the manufactures of that country, it appears that they have invented machines which perform the cutting and heading at one operation, and with such a rapidity, that one machine will furnish upwards of one hundred nails *per* minute: he says, "the importance of nail machinery in Massachusetts, and of all that relates to rolling and slitting-mills, with which nail machinery is immediately connected, requires that a particular account should be given of them. In old countries nails are forged, here they are cut, and it is curious to trace the progress of American genius through the various steps of this invention. Twenty years ago some men, now unknown, and then in obscurity, began by cutting slices out of old hoops, and by a common vice, gripping these pieces, headed them with several strokes of the hammer: by progressive improvements slitting-mills were built, and the shears and the heading tools were perfected, yet much labour and expence were requisite to make nails. In a little time, Jacob Perkins, Jonathan Ellis, and a few others, put into execution the thought of cutting and of heading nails by water, but being more intent upon their machinery than upon their pecuniary affairs, they were unable to prosecute the business. At different times other men have spent fortunes in improvements, and it may be said with truth, that more than a million of dollars have been expended; but at length these joint efforts are crowned with complete success, and we are now able to manufacture at about one-third of the expence that wrought

nails can be manufactured for, and nails which are superior to them; for at least three-fourths of the purposes to which nails are applied, and for most of those purposes, they are full as good. The machines made use of by Odiorne, those lately invented by Jonathan Ellis, and a few others, present very fine specimens of American genius.

"To northern carpenters it is well known, that in almost all instances it is unnecessary to bore a hole before driving a cut nail; all that is requisite is, to place the cutting edge of the nail across the grain of the wood: it is also true, that cut nails will hold better in the wood. These qualities are, in some rough building works, worth twenty *per cent.* of the value of the article, which is equal to the whole expence of manufacturing. For sheathing and drawing, cut nails are full as good as wrought nails: only in one respect are the best wrought nails a little superior to cut nails, and that is where it is necessary they should be clenched. The manufacture of cut nails was born in our country, and has, within its bosom, advanced through all the various stages of infancy to manhood; and, no doubt, we shall soon be able, by receiving proper encouragement, to render them superior to wrought nails in every particular.

"The principal business of rolling and slitting-mills is, rolling nail plates; they also serve to make nail rods, hoops' tires, sheet iron, and sheet copper: in this State we have not less than twelve.

"These mills could roll and slit 7000 tons of iron a-year: they now, it is presumed, roll and slit each year about 3500 tons, 2400 tons of which, probably, are cut up into nails and brads, of such a quality, that they are good substitutes for hammered nails, and, in fact, have the preference with most people for the following reasons, *viz.* on account of the sharp corner and true taper with which cut nails are formed; they may be driven into harder wood, without bending or breaking, or hazard of splitting the wood, by which the labour of boring is saved, the nail, one way, being of the same breadth or thickness from head to point." We are informed that J. C. Dyer, esq. who has had the American machinery communicated to him, to be introduced into this country, has lately taken out patents in Great Britain, with a view of establishing the trade in this country.

Nealing

NEALING, or ANNEALING, in the arts, consists in making metals red-hot, which have become hard and brittle by working, in order to restore their former malleability and tractability. All metals have the property of becoming more or less hard and unmalleable, after undergoing the operation of the hammer. Metals thus affected are more elastic than they were before, but, at the same time, they become more brittle. They are the more sensibly affected in this manner in proportion as the metals are naturally harder. Copper is so much affected, and even gold and silver, by hammering and compression, that they soon cease to be malleable, and instead of being extended under the hammer they crack and split. Hence the necessity of annealing the common coins of the country, to which we have referred under the article MINT. In all cases the labour of hammering, when it is to be long continued, must occasionally be interrupted to soften and restore malleability to metals; this is effected by making them red-hot, and suffering them to cool gradually. Thus heat produces the same effect on metals, in the state described, as it does upon tempered steel, for, if the hardest tempered steel be made red-hot and cooled slowly, it becomes as tractable and ductile as the softest iron. Articles of glass are also nealed before they are fit for use, by placing them in a furnace, and after they have been raised to a due degree of temperature, they are suffered to cool gradually. Without this operation glass vessels would be entirely useless, as they would not admit of the least change of temperature from cold to heat, nor would they bear the slightest blow. See GLASS.

NEALING of *Glass* is the baking of glass, to dry, harden, and give it the due consistence, after it has been blown, and fashioned into the proper works.

This is usually performed in a kind of tower, called the *leer*, built over the melting furnace. See GLASS.

NEALING of *Glass* is also used for the art of staining of glass with metalline colours.

One fine use of silver, says Mr. Boyle, was only discovered since the art of annealing upon glass came to be practised. For prepared silver, or even the crude metal, being burnt on a glass plate, will tinge it of a fine yellow, or golden colour. And there are several mineral earths, and other coarse matters, of use in this art, which by means of fire impart transparent colours to glass, and sometimes very different ones from those of the bodies themselves.

NEALING of *Steel*, is the heating it in the fire to a blood-red heat; and then taking it out, and letting it cool gently of itself.

This is done to make it softer, in order to engrave or punch upon it. See TEMPERING, and ENGRAVING. See also STEEL.

NEALING is also used for the art or act of burning or baking earthen or other ware in an oven.

The miners at Mendip, when they meet with a rock they cannot cut through, anneal it, by laying on wood and coal, and contriving the fire so that they quit the mine before the operation begins, it being dangerous to enter it again before it be quite cleared of the smoke. Phil. Trans. N° 39. p. 769.

NEALING of *Tile* is used in ancient statutes for the burning of tile.

The word is formed of the Saxon *onelan*, *accendere*, to light, burn.

Needle

NEEDLE, a very common little instrument, or utensil, made of steel, pointed at one end, and pierced at the other; used in sewing, embroidery, tapestry-work, &c.

Needles make a very considerable article in commerce; and the consumption of them is almost incredible. The sizes are from N^o 1, the largest, to N^o 25, the smallest. There is scarcely any commodity cheaper than needles; which will appear something extraordinary to the reader, after he has been shewn the great number of operations they undergo, before they are brought to perfection.

NEEDLES, *Manufacture of.* German and Hungarian steel is of most repute for needles. The first thing is to pass it through a coal fire, and under a hammer, and to bring it out of its square figure into a cylindrical one: this done, it is drawn through a large hole of a wire-drawing iron, returned into the fire, and drawn through a second hole of the iron, smaller than the first; and thus successively from hole to hole, till it has acquired the degree of fineness required for that species of needles; observing every time it is to be drawn, that it be greased over with lard to render it the more manageable. The steel, thus reduced into a fine wire, is cut in pieces of the length of the needles intended. These pieces are flattened at one end, on the anvil, in order to form the head and eye: they are then put into the fire, to soften them farther; and thence taken out and pierced at each extreme of the flat part, on the anvil, by the force of a puncheon of well tempered steel, and laid on a leaden block, to bring out, with another puncheon, the little piece of steel remaining in the eye.

The corners are then filed off the square of the heads, and a little cavity filed on each side the flat of the head. This done, the point is formed with a file; and the whole filed over.

They are then laid to heat red-hot, on a long, flat, narrow iron, crooked at one end, in a charcoal fire; and, when

taken out thence, are thrown into a basin of cold water to harden. On this operation a good deal depends; too much heat burns them, and too little leaves them soft; the medium is only to be learnt by experience.

When they are thus hardened, they are laid in an iron shovel, on a fire, more or less brisk, in proportion to the thickness of the needles; taking care to move them from time to time. This serves to temper them, and take off their brittleness; great care, here too, must be taken of the degree of heat. They are then straightened, one after another, with the hammer; the coldness of the water, used in hardening them, having twisted the greatest part of them.

The next process is the polishing. To do this, they take twelve or fifteen thousand needles, and range them in little heaps against each other, on a piece of new buckram, sprinkled with emery dust. The needles, thus disposed, emery-dust is thrown over them, which is again sprinkled with oil of olives: at last, the whole is made up into a roll, well bound at both ends.

The roll is then laid on a polishing-table, and over it a thick plank, loaded with stones, which two men work backwards and forwards, a day and an half, or two days successively; by which means the roll, thus continually agitated by the weight and motion of the plank over it, the needles withinside, being rubbed against each other with oil and emery, are insensibly polished.

In Germany, instead of hands, they polish with water-mills.

After polishing, they are taken out, and the filth washed off them with hot water and soap: they are then wiped in hot bran, a little moistened, placed with the needles in a round box, suspended in the air by a cord, which is kept stirring till the bran and needles be dry.

The needles, thus wiped in two or three different brans, are taken out, and put in wooden vessels, to have the good

separated from those whose points or eyes have been broken, either in polishing or wiping: the points are then all turned the same way, and smoothed with an emery-stone, turned with a wheel.

This operation finishes them; and there remains nothing but to make them into packets of two hundred and fifty each.

NEEDLES, *Surgeons'*, are generally made crooked, and their points triangular: however, they are of different forms and sizes, and bear different names, according to the purposes they are used for.

The largest are needles *for amputation*; the next, needles *for wounds*; the finest, needles *for sutures*. They have others, very short and flat, for tendons; others, still shorter, and the eye placed in the middle, for tying together of vessels, &c. Needles for couching cataracts are of various kinds; all of which have a small, broad, and sharp point or tongue: and some with the fulcus at the point. Surgeons have sometimes used two needles in this operation, one with a sharp point for perforating the coats of the eye, and another with a more obtuse point for depressing or couching the opaque crystalline lens: but care should be taken in the use of any of these, that they be first well polished, with cloth or leather, before they are applied to the eye. See CATARACT and COUCHING.

Mr. Warner observes, that the blade of the couching needle should be at least a third part larger than those generally used upon this occasion, as great advantage will be found in the depressing of the cataract, by the increased breadth of the blade of that instrument. The handle, also, if made somewhat shorter than usual, will enable the operator to perform with greater steadiness than he can do with a larger handled instrument.

It is to be observed, that needles of silver pierce more easily in stitching arteries after an amputation, than those made of steel. *Monro, in Med. Ess. Edin. vol. v. art. 41.*

NEEDLE, *Magnetical*, in *Navigation*, denotes a needle touched with a loadstone, or sustained on a pivot or centre, on which, playing at liberty, it directs itself to certain points in or under the horizon. See MAGNET.

Magnetical needles are of two kinds; *viz. horizontal and inclinatory.*

NEEDLES, *Horizontal*, are those equally balanced on each side the pivot which sustains them: and which, playing horizontally with their two extremes, point out the north and south points of the horizon. For their application and use, see COMPASS.

NEEDLE, *Construction of an Horizontal*. A piece of pure steel is procured, of a length not exceeding six inches, lest its weight impede its volubility; very thin, to take its verticity the better; and not pierced with any holes, or the like, for ornament sake, which prevent the equable diffusion of the magnetic virtue.

A perforation is then made in the middle of its length, and a brass cap or head soldered on, whose inner cavity is conical, so as to play freely on the style or pivot, headed with a fine steel point.

The north point of the needle, in our hemisphere, is made a little lighter than the southern, the touch always destroying the balance, if well adjusted before; and rendering the north end heavier than the south, and thus occasioning the needle to dip.

Now to give the needle its verticity, or directive faculty, it is to be rubbed leisurely on each pole of a magnet, from the south pole towards the north; first beginning with the northern end, and going back at each repeated rub toward

the south. A rub in a contrary direction takes away the power communicated by the former.

Compass needles may acquire the magnetic virtue by means of magnetic bars in the following manner: lay two needles of equal length, about an inch asunder, with the north end of one, and the south end of the other pointing the same way, and applying two conductors in contact with their ends: then, with two magnetic hard bars, one in each hand, and held as nearly horizontal as can be, with the upper ends, of contrary names, turned outwards to the right and left, let a needle be stroked or rubbed from the middle to both ends at the same time, for ten or twelve times, a north end of a bar going over the south end of the needle, and the south end of a bar going over the north end of a needle: then, without moving from the place, change hands with the bars, or, in the same hands, turn the other ends downwards, and stroke the other needle in like manner, and they will both be magnetical: but to make them still stronger, repeat the operation three or four times from needle to needle; and at last turn the lower side of each needle upwards, and repeat the operations of rubbing them, as on the other sides.

In the rubbings or touchings to procure magnetism, the hand should not return directly back the way it came, but should return in a kind of oval figure, carrying the hand about six or eight inches beyond the point, where the touch ended; but not beyond, on the side where the touch begins.

If, after touching, the needle be out of its equilibrium, something must be filed off from the heavier side, till it balance evenly. See MAGNET.

The needles that were formerly applied to compasses, on board our merchant ships, were formed of two pieces of steel wire; each of which was bent in the middle, so as to make an obtuse angle; and their ends being applied together made an acute one; so that the whole represents the form of a lozenge. Dr. Knight, to whom we are indebted for the improvement of the compass, found, by repeated experiments, that these needles not only varied from the true direction, but from one another, and from themselves: and he has shewn that these irregularities were owing to their structure: for the wires of which the needle was composed were hardened only at their ends; now if those ends are not equally hard, or if one end be hardened higher up than the other, when they come to be put together, in fixing them to the card, that end which is hardest will destroy much of the virtue of the other; by which means the hardest end will have the greatest power in directing the card, and consequently make it vary towards its own direction: and as the wires are disposed in the form of a lozenge, these cards can have but little force; so that they will often, when drawn aside, stand at the distance of several degrees on either side the point from whence they are drawn; for all magnetical bodies receive an additional strength by being placed in the direction of the earth's magnetism, and act proportionably with less vigour when turned out of it. Therefore, when needles of this kind are drawn aside from their true point, two of the parallel sides of the lozenge will conspire more directly than before with the earth's magnetism, and the other two less in that direction: by this means the two former sides will very much impede its return, and the two latter will have that impediment to overcome, as well as the friction, by their own force alone.

The needles formerly used on board the men of war, and some of the larger trading ships, were made of one piece of steel, of a spring temper, and broad towards the ends, but tapering towards the middle. Every needle of this form is found to have six poles instead of two; one at each end,

two where it becomes tapering, and two at the hole in the middle. This inconvenience is owing to their shape; for the middle part, being very slender, has not substance enough to conduct the magnetic stream quite through from one end to the other. In order to avoid these inconveniences and errors, the needle, contrived by Dr. Knight for his compass, is quite straight and square at the ends, and consequently has only two poles, although the curves are a little confused about the hole in the middle. Needles of this construction, after vibrating a long time, will always point exactly in the same direction; and if drawn ever so little on one side, will return to it again, without any sensible difference. Hence Dr. Knight concludes, that a regular parallelopiped is the best shape for a needle, as well as the simplest; with the holes for the caps as small as can be well contrived; or if it can be made to answer the purpose, without any hole at all, it will be still more perfect.—There is a peculiar advantage attending Dr. Knight's needles; for as they are tempered much higher than usual, they are able to contain a much greater quantity of the magnetic force. See COMPASS.

Mr. Michell suggests, that it would not be amiss to cover the needles made use of in the sea-service, with a very thin coat of linseed oil, or some kind of varnish, that may keep them from rusting, which is generally reckoned to injure all magnetical bodies that are liable to it. Needles may be touched through such a coat, by applying a great number of bars, if not according to the common method of making

magnets. He also apprehends, that coated needles may retain a greater degree of magnetism, than they otherwise would do.

Mr. Michell also proposes to increase the weight and length of mariners' needles; and he observes, that long needles, properly hung, traversing to a greater degree of exactness than the short ones, may be of considerable service on many occasions: particularly in mines for discovering the bearing of one place from another, that they may be able to sink a shaft from above, over any place at pleasure. In many sorts of mines, especially those of coal, there are often small quantities of magnetical iron ore, which draw the needle out of its proper direction; now the long needles are less liable to be disturbed by any small things, already magnetical, than shorter ones. Michell on Magnets, p. 42, &c.

A needle, on occasion, may be prepared without touching it on a load-stone: for a fine steel needle, gently laid on the water, or delicately suspended in the air, will direct itself to the north and south.

Thus also a needle, heated in the fire, and cooled again in the direction of the meridian, or even only in an erect situation, acquires the same faculty.

The needle is not found to point precisely to the north, except in very few places; but deviates from it, more or less, in different places, and that too at different times; which deviation is called the *declination*.

New River

NEW RIVER, a most important artificial canal, or stream of water, passing through parts of the counties of Hertford and Middlesex, England, was contrived and principally executed by an individual, sir Hugh Middleton, in order to supply the British metropolis and its environs with fresh water. That of the Thames, though extremely beneficial to London, was so liable to alteration, and subject to foulness, that a copious supply of pure water was extremely desirable. Besides, the Thames water must be forced to ascend by machines, even for the lower parts of the city: whereas, a stream on the northern side of London may be made to flow, in a natural descent, to almost any quarter of the widely extended metropolis. From these considerations, in the reign of James I., Hugh Middleton, citizen and goldsmith, projected the plan of bringing water out of Hertfordshire, in a channel to London. Meeting with no co-operation, he, at length, in the year 1608, commenced the undertaking at his own expence; and, after exhausting all his resources, and being refused aid from the corporation of London, he was enabled, by the assistance of the king, to bring it to completion. On September 29, 1613, the water was let into the New River Head, at Islington; but the projector was ruined by the expences, and it was long before the scheme was rendered useful and beneficial to the public. The New River is formed by the collected waters of several springs, which rise at Chadwell, near Ware, Hertfordshire, about 20 miles north-west from London. These springs are collected into a large, open basin of considerable depth, near which a stone is placed, with inscriptions, implying that the stream was opened in 1608, and that from the Chadwell spring the river flows 40 miles. The original supply of water having been found inadequate to the consumption, the mill-stream of the river Lea, which runs near it, was resorted to; and after various disputes and litigations between its proprietors and those of the New River, the mill has at length become the property of the latter company, who have now an unrestricted use of the water; so that the river Lea may be considered as one of the sources. On a sluice leading from it are flood-gates, with a building, in which a man is placed, whose constant employ is to raise or lower them, according to the fulness of the river below; and that he may not err in the quantity supplied, a gauge is fixed across the sluice, consisting of a stone of great bulk, under which all the water passes; so that the current is regulated with the greatest exactness. To preserve a proper

level, the New River takes such a winding course, that the length of the channel is nearly thirty-nine miles. Passing Ware, Amwell, Hoddesdon, and Cheshunt, it enters Middlesex near Waltham-Cross; bending towards Enfield-Chase, it returns to the town of Enfield; and at Bush-hill was formerly carried across a valley, in a wooden aqueduct, or open trough, 660 feet in length, supported by arches; but the improvement in canal making has suggested a better mode to effect the purpose by means of a mound of earth, over which the river passes in a new channel, which was completed in the year 1785. Hence the river proceeds with various bends to Hornsey, between which village and High-bury it was formerly conveyed in another wooden aqueduct, now superseded, like the other, by a bank of clay. Still winding, it reaches Stoke-Newington, and passes on to the east side of Islington, where it has a subterraneous channel, for 200 yards beneath the street. Just before this part is a building, whence several mains, or pipes, are sent to supply the eastern side of London. After passing under the road, the New River emerges and coasts the southern side of Islington, till it reaches its termination at the grand reservoir, called the New River Head. The width of the river near Islington is fourteen feet and a half, the average depth four feet and a half, but the depth decreases on ascending towards its source. The number of bridges which cross the river in its whole course is about two hundred: in various places are sluices to let off the waste water; which, with other works, excited admiration in the earlier stage of this branch of mechanics, but are now overlooked in the wonders of canal navigation. Truly admirable are the contrivances for distributing the water through the various parts of London. From a circular basin, now thrice its original size, which first receives it, the water is conveyed by sluices into several large brick cisterns; whence it passes through large wooden pipes to the several districts, and is conveyed into the houses by leaden pipes. At the New River Head is a building, containing two steam-engines and a water-engine for forcing the water to a higher reservoir near Pentonville, and to another near Tottenham-court road, for distribution to the western parts of the town. Near the former reservoir, in a field, a conspicuous object appears, the use of which is little known. It is an iron pipe, twelve feet high, and four feet eight inches in circumference, with a wooden tub placed on its top. It acts in the double capacity of an air and waste water-pipe, and is useful in preventing the burst-

ing of the pipes, which was formerly very frequent from the force of water, or from compressed air. A new reservoir, communicating with that at Pentonville, has been recently constructed by the side of Tottenham-court-road, for the supply of Mary-le-bone and its vicinity: the mains from it are iron pipes of four feet eight inches circumference.

The property of this great concern was originally divided into 72 shares, of which 36 were vested in sir Hugh Middleton, who was obliged to part with them to various persons; these are termed adventurers' shares. The other thirty-six were vested in the crown for the money advanced by king James towards the undertaking. These were alienated by Charles I., and are called king's shares; but as the crown had no concern in the management, so the holders of these shares are excluded from the direction. The original value of the shares was 100*l.* each, but so discouraging were the first prospects, that they fell to a very low price. At present they are worth an hundred times their first value:

a rise in property scarcely to be paralleled, and demonstrative of the increase of buildings in the capital. The management of the company's affairs is vested, by charter, in twenty-nine holders of adventurers' shares, who form a board. The officers are, a governor, deputy-governor, a treasurer, and a clerk. Few public companies surpass this in property and extent of concerns. The constant repairs and improvements employ a vast number of men and horses; and the whole system of the distribution of the water is so complicated, as to require the utmost skill and attention on the part of the surveyor and other officers.

The New River is a considerable ornament to many seats and pleasure-grounds in its course; though it has too much canal-like regularity to be truly picturesque. It is likewise of great utility in affording a supply of water for cattle, and for various other purposes. Hunter's History of London and its Environs, 4to. 1808. Brayley's History of Middlesex and London, 8vo. 1810-13.

Newton

NEWTON, *Sir ISAAC*, the most illustrious of philosophers and mathematicians that the world ever produced, and who, on account of his well-earned celebrity, has been denominated the "Prince of Philosophers," was born on Christmas-day 1642, at Woolthorpe, a hamlet in Lincolnshire, about six miles south of Grantham. His father cultivated his own paternal estate, but is represented as being a very weak and unsteady man, who died three months before the birth of his only son Isaac, the subject of the present article. Mrs. Newton, though she married again, was particularly attentive to the education of her first-born, and had him carefully instructed in the elements of learning. At the grammar-school of Grantham he laid a solid foundation of classical

learning, and gave decisive marks of his natural genius. Dr. Stukely, in speaking of him, says, "Every one that knew Sir Isaac, or have heard speak of him here, recount the pregnancy of his parts when a boy, his strange inventions, and extraordinary inclination for mechanics, that, instead of playing with other boys, when out of school, he always busied himself in making knickknacks, and models of wood in many kinds; for which purpose he had got little saws, hatchets, and hammers, and a whole shop." The most trifling circumstances, relating to so vast a genius as Sir Isaac Newton exhibited, are deserving of record: hence may be mentioned his very early attention to natural objects and investigation. He had, for instance, when a very little

child, a rude method of measuring the force of the wind, by observing how much farther he could leap in the direction of a strong breeze, than he could when he jumped against the wind. When he quitted the grammar-school, he was taken home to be instructed in rural affairs, in order that he might hereafter be capable of managing his own estate with advantage. It was, however, soon discovered that he had higher objects in view than the mere cultivation of land, and attending to domestic concerns: he was perpetually found reading books, which were supposed to be beyond his capacity. He had, previously to this, probably laid it down as a maxim, that what one man could write, that was in itself intelligible, another might, by a certain portion of application, come to understand. Being once sent to Grantham market, he was discovered by his uncle, in a hay-loft, working a mathematical problem; which satisfied this relation that his desire of knowledge was invincible, and that a regard ought to be paid to the turn of his mind: he, therefore, without hesitation, was allowed to enter himself, in the year 1660, of Trinity-college, Cambridge. He was now 18 years of age, and entering upon his course with all the ardour of enthusiasm, much might be expected from him; but, as we shall see, he outran all expectation, and set at defiance the calculations of his most sanguine friends. The activity of his genius, and excellence of his talents, acquired for him the notice of the most considerable mathematicians in the university, among whom was Mr. (afterwards Dr.) Barrow, at that time a fellow of Trinity-college. The friendship thus begun between these two persons, was continued till the hand of death separated them. Newton began his studies with the "Elements of Euclid;" but these did not detain him long. To him there was no "Pons Asinorum," no difficulty that impeded his progress a single moment: he saw the truth of each proposition, it has been said upon unquestionable authority, as soon as he had read the enunciation, and examined the figure to which it referred. The beautiful and sublime truths of common geometry did not, to Newton, lie deep in a well: they seemed instantly to fasten on his mind, and, as he thought, to urge him on to more difficult steps in the progress of science. Afterwards, however, the ingenuousness of his mind led him to regret that he had not stopped longer at the gates of knowledge;—that he had not rested a while in the avenues to contemplate the beauties and excellencies of the plans and outworks, before he had proceeded into the interior;—that he had not examined with a more minute attention Euclid's method of demonstration, and the means by which he had contrived to connect every part of his book, so as to make a system or series of truths depending upon one another, and the whole resting on definitions and axioms; though the axioms themselves will, if closely examined, be found to be only definitions: so that the whole of Euclid's Elements may be safely said to depend entirely on definitions, which proves how important it is for students in geometry, not endowed with peculiar mathematical sagacity, to study with the utmost care the definitions, and to proceed from one step to another with the greatest deliberation. Newton, as we have seen, did not stand in need of this precaution; yet he regretted in after life, that "he had committed a mistake in the commencement of his mathematical studies, in applying himself to the works of Des Cartes, and other algebraical writers, before he had considered the Elements of Euclid with that attention which so excellent a writer deserves." At this period the works of Des Cartes were much in fashion, which of course led our author to study them, attending at the same time to "Kepler's Optics," and to the "Arithmetica Infinitorum" of Dr. Wallis, making improvements and marginal notes upon them as he

went along, which was his usual method of studying any author. The treatise of "Infinities," just referred to, set his invention to work; and was probably that which led him to his "New Method of Infinite Series and Fluxions," and which was published in Latin; but which, in 1736, was translated into English by Mr. Colson, and printed by him, with a perpetual Commentary upon the whole book. In the year 1664 he took his degree of B.A., and about this period he turned his attention to the improvement of telescopes. Des Cartes assuming the commonly received opinion, that light was homogeneous, had, upon this principle, discovered the laws of refraction, and maintained that the perfection of telescopes depended on the discovery of a method of making glasses in elliptic, parabolic, or hyperbolic figures. Newton, therefore, in the year 1666, applied himself to the grinding of optical glasses of divers figures; at that time not suspecting that light was other than an homogeneous substance. Not succeeding in various attempts which he made, he procured a glass prism, for the purpose of examining the phenomena of colours, which had lately been discovered by Grimaldi. The vivid brightness of the colours produced by this experiment at first afforded him very great pleasure; but when his surprise was over, and he came to examine them with philosophical accuracy, he was astonished at seeing them in an oblong form, which he thought should be circular. He imputed the irregularity, at first, to some accidental circumstance of which he was not aware: when, however, he found the result uniformly the same in every experiment, he pursued the inquiry, till at length he discovered an infallible method of deciding the point, which produced his "New Theory of Light and Colours." This theory, unexpected and wonderful as it was, did not satisfy him; but urged him on to inquire into the use that might be made of it in improving telescopes, which was his first design. Having now ascertained that light was not homogeneous, but a heterogeneous mixture of differently refrangible rays, he computed the errors arising from this different refrangibility; and finding them to exceed some hundreds of times those occasioned by the circular figure of the glasses, he began to study the subject of reflection with the utmost care. He was now convinced that optical instruments might be brought to any degree of perfection, provided a substance could be found which would bear a polish as finely as glass, and reflect as much light as glass transmits, and that the art of giving it a parabolic figure could be attained. These desiderata he did not suppose could be realized; but while his mind was intently occupied by the speculation, the breaking out of the plague at Cambridge, in 1665, obliged him suddenly to quit his studies and his books, and retire into the country. From this time, for a space of about two years, Newton lived, in a great degree, secluded from the conversation and the society of those persons, by whom he might have been assisted in his studies; but the activity of his genius would not permit him to spend this period without engaging in important philosophical inquiries. It was, indeed, in the solitude now referred to, that the hint occurred which gave rise to the System of the World, which is the main subject of his "Principia." As he was sitting alone in a garden, an apple falling from a tree, led his thoughts to the subject of gravity; and reflecting on the operation of that principle, he began to consider that, as this power is not found sensibly diminished at the remotest distance from the centre of the earth to which we can rise, neither at the tops of the loftiest buildings, nor on the summits of the highest mountains, it was reasonable to conclude that it must extend much farther than was usually imagined. "Why not," said he to himself, "as high as the moon? and if so, her motion must be

influenced by it. Perhaps she is retained in her orbit by it. Though the power of gravity is not sensibly weakened in the little change of distance at which we can place ourselves from the centre of the earth, yet it is very possible that, as high as the moon, this power may differ in strength much from what it is here." He made the calculation; but having gone upon wrong data, in supposing 60 miles to make a degree, instead of $69\frac{1}{2}$, the result did not come out according to his expectations: he therefore concluded, that some other causes must be joined with the action of the power of gravity on the moon; and on this account he laid aside, for that time, any further thoughts upon the subject. On his return to Cambridge, in 1667, he was elected fellow of his college, and took his degree of M.A. He now was anxious to improve the telescope, and had made preparations for his experiments, when his attention was interrupted by the business connected with the professorship of mathematics, which Dr. Barrow resigned to him in 1669. Having entered upon the office, he made his discoveries in optics the subject of his lectures, for the first three years after his appointment to the mathematical chair: and having brought his theory of light and colours to a considerable degree of perfection, he communicated it to the Royal Society, of which he was a member; and it was afterwards published in their Transactions, for the month of February 1672. The publication gave rise to a controversy that occasioned him much uneasiness, so that he resolved not to publish any thing further, for a time at least, on the subject; and accordingly he laid aside his optical lectures, although they were actually prepared ready for the press. His analysis by infinite series underwent the same fate. He now resumed his telescope, and observing that there was no absolute necessity for the parabolic figure of the glasses, he completed another instrument of this kind. This answered his purpose so well, that, though it was only six inches long, he had seen with it the satellites of Jupiter, and the different phases of Venus. This telescope he sent to the Royal Society, at their request, together with a description of it, published in the Philosophical Transactions for March 1672.

During this year Mr. Newton published at Cambridge "*Bernardi Varenii Geographia generalis, in qua affectiones generales Telluris explicantur; aucta et illustrata ab J. Newton.*" From this time till 1679 our author maintained a correspondence with Mr. Henry Oldenburg, secretary of the Royal Society, Mr. John Collins, Mr. Flamsteed, and Dr. Halley. During this period, at the request of Leibnitz, he explained his invention of infinite series, and shewed how far he had improved it by his method of fluxions, which, however, he still concealed by a transposition of the letters that made up the fundamental propositions of it into an alphabetical order. The letters concerning this are inserted in Collins's "*Commercium Epistolicum*," printed in 1712. In 1676-7, he discovered the grand proposition, that, by a centripetal force acting reciprocally as the square of the distance, a planet must revolve in an ellipse, about the centre of force placed in its lowest focus, and, by a radius drawn to that centre, describe areas proportional to the times. About the year 1680 he made many astronomical observations upon the comet that then appeared; which, for some considerable time, he took not to be one and the same, but two different comets, contrary to the opinion of Mr. Flamsteed. He next resumed his enquiries respecting the moon. As Picart had measured a degree of the earth in 1679, by using his measures, Newton was led to the inference that the moon is retained in her orbit solely by the power of gravity, and, consequently, that this power decreases in the duplicate proportion of the distance, as he had formerly conjectured. Hence he found

the line described by a falling body to be an ellipse, having one focus in the centre of the earth; and ascertaining, by this means, that the primary planets really moved in such orbits as Kepler had supposed, he had the satisfaction to see that the enquiry, which he had undertaken, at first, from motives of mere curiosity, was capable of being applied to the most important purposes. Upon this he drew up, and afterwards demonstrated, about a dozen propositions relating to the motions of the primary planets round the sun, which he communicated to the Royal Society towards the close of the year 1683. Shortly after this he set down to complete his great work, the "*Principia*," which was printed under the care of Dr. Halley, and published in the summer of 1687, under the title of "*Philosophiæ Naturalis Principia Mathematica*." This treatise was composed by the illustrious author from scarcely any other materials than the few propositions above-mentioned, and in the space of a year and a half: it has gone through a great number of editions, though it did not at first meet with that sort of applause to which it was justly entitled. One reason of this was, that Des Cartes had then got full possession of the world, and his philosophy was supposed to be better adapted to common understandings. The "*Principia*," on the other hand, is in many places extremely difficult, owing to the number of steps which is left out in the demonstrations, so that the best mathematicians were obliged to study it with care, before they could pretend to become masters of this vast treasure of human learning. And notwithstanding the helps that we now have to the right understanding of the "*Principia*," in Maclaurin's and Pemberton's works; in the "*Excerpta*" of Dr. John Jebb, and in the Commentaries of the Jesuits, published at Rome in four volumes quarto; still it may be assumed that "none but mathematicians of a high order can completely comprehend the reasonings contained in it. When, however, the true value of this work came to be known, the approbation which had been so slowly gained became universal, and nothing was heard from all quarters, but admiration of what seemed to be the production of a celestial intelligence, rather than of a man." "Does Mr. Newton eat, or drink, or sleep like other men?" said the marquis de l'Hospital, one of the greatest mathematicians of the age, "I represent him to myself," he added, "as a celestial genius entirely disengaged from matter."

A short time before this work went to the press, the privileges of the university of Cambridge were attacked by king James II., who sent a *mandamus* to admit father Francis, an ignorant Benedictine monk, to a degree of M.A. On this occasion Mr. Newton appeared among the most zealous and active defenders of that body, and was appointed one of the delegates to the high-commission court, where they maintained their cause with such resolution and steadiness that the king did not think it right to press the affair. Newton was, after this, chosen one of the representatives of the university in the convention-parliament of 1688, the sessions of which he attended till its dissolution. In 1696, Mr. Newton was appointed to the office of warden of the mint, and in this situation he rendered very important service to the nation, and was properly rewarded, in a few years, with the appointment of master of the mint, a place worth 1200*l.* *per annum*, which he held during the remainder of his life. Upon the promotion he resigned the mathematical chair at Cambridge, and was succeeded in it by Mr. William Whiston. In 1699 he was elected a foreign member of the Royal Academy of Sciences at Paris, and in 1703 he was chosen president of the Royal Society of London, and retained that honourable office till his death. In the following year he published his "*Optics; or A Treatise of the Reflections,*

Refractions, Infections, and Colours of Light." This work was the result of his occasional labours for thirty years in bringing the experiments, on which his "New Theory of Light and Colours" is founded, to that degree of certainty and exactness which alone could satisfy himself. This seems to have been his favourite invention: he was the first person who conceived the idea, and engaged in the subtle and delicate study of the anatomy of light; who dissected a ray of light into its primary constituent particles, which then admitted of no farther separation; who discovered the different refrangibility of the particles thus separated, and that these constituent rays had each its own colour inherent in it. On this subject we could enlarge would our limits allow. With the approbation of the author, Dr. Samuel Clarke translated the "Optics" into the Latin language, and he did the business so much to the satisfaction of Mr. Newton, that he presented him with 500*l.* for his labour. It was published in 1706. With the first edition of his Optics, the author published his "Quadratures of Curves," which may be regarded as the earliest appearance, in print, of his Method of Fluxions, which he had invented in the years 1665 and 1666. M. Leibnitz had, since the year 1684, endeavoured to impress the world with the persuasion, that Newton had borrowed this invention from his "Differential Method;" when, therefore, our illustrious countryman laid claim to his own discovery it led to much altercation, but the learned world in general decided in favour of Newton; and Fontenelle, in speaking on the subject, says, "Sir Isaac was, by many years, the first inventor. M. Leibnitz, on the other side, was the first who published this method of calculation; and if he took it from sir Isaac Newton, he resembled Prometheus in the fable, who stole fire from heaven that he might communicate it to men." See our article *KELL, John*.

In the year 1705, queen Anne conferred on Mr. Newton the honour of knighthood: two years after this, Mr. Whiston, by our author's permission, published his Algebraical Lectures, under the title of "Arithmetica Universalis, five de Compositione et Resolutione Arithmetice Liber," which work was translated into English by Mr. Raphson. In 1711, our author's "Analysis per Quantitatum Series, Fluxiones et Differentias, cum Enumeratione Linearum tertii Ordinis" was published by William Jones, esq. F.R.S., who met with a copy among the papers of Mr. Collins, to whom it had been communicated by Dr. Barrow. It was published in consequence of the dispute relating to the invention of fluxions, which also occasioned the printing, in 1712, by the consent of sir Isaac, a Collection of Letters, already referred to, by him and others in that controversy, under the title of "Commercium Epistolicum D. Johannis Collins et aliorum, de Analysis promota, jussu Societatis Regiæ in Lucem editum." In the year 1715, M. Leibnitz, with the view of gaining credit to the pretension that the "Method of Fluxions" had been borrowed from his "Differential Method," attempted to baffle sir Isaac Newton's mathematical skill by his famous problem of his Trajectories, which he proposed to the English by way of challenge; but though it was the most difficult proposition which his ingenuity, after much study, was able to devise, the solution of it proved scarcely more than an amusement to Newton. The problem was received by him at four o'clock in the afternoon, as he was returning from the mint, and though he was extremely fatigued with business, yet he finished the solution of it before he retired to bed.

Upon the accession of king George I. to the British throne, sir Isaac was particularly noticed at court, and was specially introduced to the princess of Wales, afterwards

queen Caroline, who took great delight in literary and philosophical enquiries, and in the conversation of men distinguished by their talents and knowledge. With that of our author she was always peculiarly gratified, deriving from it that full satisfaction in every difficulty, which she had in vain sought for elsewhere, and she did not scruple to say that she thought herself happy in coming into the world at a juncture of time which put it in her power to converse with sir Isaac Newton. At the solicitations of this princess he drew up an abstract of his "Chronology," and communicated a copy of it to the abbé Conti, upon the promise of his keeping it secret; instead of which he had it translated and printed at Paris, under the title of "Abregé de Chronologie de M. Le Chevalier Newton, fait par lui-même et traduit sur le Manuscrit Anglois:" a copy was sent to sir Isaac by the bookseller who printed it, under the pretence of asking his consent to the publication; but though he gave a direct and most explicit denial, the work was sent into the world in the course of the year. He accordingly found it necessary to enter into a vindication of himself, which was inserted in the 34th volume of the Philosophical Transactions, under the title of "Remarks upon the Observations made upon a Chronological Index of sir Isaac Newton, translated into French by the Observator, and published at Paris." Of this paper a translation appeared at Paris in 1726, with a letter of the abbé Conti in answer to it. In the same year, likewise, some dissertations were published at Paris by father Souciet, against the "Chronological Index," a reply to which, by Dr. Halley, was given in the 397th Number of the Phil. Transf.

Our philosopher enjoyed a regular and pretty equal state of health until he attained his eightieth year, when he began to decline: his illness was supposed to be occasioned by a stone in the bladder, which at times was attended with such paroxysms of pain as caused large drops of sweat to roll down his face. During these attacks he was never heard to utter the least complaint, nor to express any impatience, and as soon as he had a moment's ease he would smile and converse with his usual cheerfulness. Till this period he had always read and written for several hours in a day, but he was now rendered incapable of much application. On the morning of the 18th of March 1726-7, he read the newspaper, and conversed for a considerable time with Dr. Mead, his physician, having then the perfect use of his faculties, of which he was, however, deprived in the course of the following night, and he breathed his last on the 20th of the same month, being in the 85th year of his age. Splendid funeral honours were paid to his remains, in a manner, in every respect, suitable to his extraordinary merit, and that high estimation in which he was deservedly held in every part of Europe. His body lay in state in the Jerusalem chamber, adjoining the house of lords; and at the interment the pall was supported by the lord chancellor, the dukes of Montrose and Roxburgh, and the earls of Pembroke, Suffex, and Macclesfield.

In contemplating the character and genius of this great man, it is not easy to determine whether sagacity, penetration, strength, or diligence had the greatest share in his composition. He entertained a very modest opinion of his own abilities, saying, when complimented on the extraordinary powers of his mind, if he had done any thing worthy of notice, and of service to the world, it was owing more to his industry and patience of thought, than to any extraordinary sagacity. "I keep the subject constantly before me," said he, "and wait till the first dawns open slowly, by little and little, into a full and clear light." When engaged in the solution of difficult problems, he was often so completely lost to the world as to forget the common

concerns of life. He has been known to sit for hours on the side of his bed with his clothes half on and half off, absorbed in thought; at other times he has gone through the day without food, having forgotten the wants of nature, in the contemplation of some mathematical truth. Our author's temper is said to have been so mild and equal, that scarcely any accident could disturb it. One instance in particular is mentioned of this disposition. He had a favourite little dog called Diamond, which being left in his study, had overset a lighted candle, among his papers, and burnt the almost finished labours of many years. This loss was irretrievable, yet the philosopher only exclaimed, "O Diamond! Diamond! thou little knowest the mischief thou hast done."

It should be noted that sir Isaac Newton was candid and affable, and always put himself upon a level with his company. He never thought either his own merit or reputation sufficient to excuse him from any of the common offices of social life; and no singularities, either natural or affected, distinguished him from other men. With respect to his religious sentiments, he was unquestionably a firm believer in the truth of divine revelation, and a serious, rational Christian. His discoveries concerning the frame and system of the universe, he employed to demonstrate the existence of a God, against Atheism of all kinds, and to il-

lustrate his power and wisdom in the creation of the world; and he applied himself with the utmost attention to the study of the sacred writings, and considered the several parts of them with uncommon exactness. He adhered, outwardly, to the communion of the church of England, though he did not believe in all its doctrines: with respect to the person of Christ, there seems no doubt that sir Isaac Newton was inclined to Unitarianism; for this we have the testimony of his friend and co-operator in the mint, Mr. Hopton Haynes, independently of his own writings. Sir Isaac was never married, and Fontenelle says he never had time to think of it, taken up as he was, at first in profound and continual study, and afterwards employed in an important and considerable post, which left no vacancy in his life, nor any occasion for domestic society. He died rich, and intestate. His library has descended to the present times, in his own family, and at the moment of writing this article (March 27, 1813,) it is selling by auction in London, by order of the executors of Mrs. Ann Newton. (See *NEWTONIAN Philosophy*.) For a notice of our author's works not mentioned in this article the reader is referred to the *Biographia Britannica*: the most complete edition of them, collectively, was given to the public by Dr. Horsley in 1785, in 5 vols. royal 4to. See *HORSLEY. Biog. Brit.* Pemberton's and Maclaurin's Views, &c.

Nickel

NICKEL, in *Chemistry*, a simple substance, and a metal of a white colour. When obtained perfectly pure it is malleable. Its lustre is agreeable, and at some period it may become of importance in the arts, and in domestic economy.

Affay and Analysis of Nickel.—This metal is generally obtained from a mineral of a reddish-brown colour, frequently spotted with green, found plentifully in different parts of Germany. This ore was formerly thought to be copper ore, from its green spots, but in consequence of its affording no copper, it obtained the name of *kupfer nickel*, which means false copper. This mineral chiefly consists of nickel and sulphur, but contains more or less of arsenic, cobalt, and iron. The first experiments to ascertain the nature of this mineral were by Cronstedt in 1751, who was of opinion that he had obtained a peculiar metal from it, to which he gave the name of nickel. What he procured, however, was not pure nickel, in consequence of which the authority of this chemist was doubted by Sage and Monnet. This point was at last finally settled by Bergman, who proved it to be a new metal. The experiments were published in 1775. The purification of this metal has been since carried to a greater extent by different chemists. The following is the most approved process for obtaining the oxyd of this metal in a state of purity, from which the metal is afterwards easily obtained.

After the ore above-mentioned has been roasted with charcoal, which may probably expel some of the arsenic, it must be reduced to a fine powder, and treated with nitric acid. The remaining sulphur will be separated, or, with the arsenic, converted into sulphuric and arsenic acids. If to a solution nitrat of lead be added, these acids will be precipitated by the lead in the state of sulphat and arseniat of lead. If too much nitrat of lead be added, the lead may be precipitated by adding small portions of sulphuric or rather sulphat of soda, till no more precipitates take place. The solution now contains nickel, iron, and perhaps cobalt and copper. The copper may be separated by a clean bar of iron. The solution must now be treated with carbonat of potash, by which the three oxyds will be precipitated together. These being washed, the nickel and cobalt may be dissolved in pure ammonia, while the oxyd of iron will be left behind. This ammoniacal solution is next heated, till the ammonia is driven off, which is known by

its ceasing to tinge turmeric paper brown. If to these oxyds pure potash be added, the oxyd of cobalt will be dissolved, while that of nickel will be left in a state of purity. The oxyd of nickel is now to be made into a paste with oil or fat, and introduced into a crucible, with some black flux. The crucible should be lined with charcoal, and provided with a close cover; the whole must be heated strongly in a smith's forge for more than an hour. On cooling a button of pure nickel will be found.

This metal, as has been remarked, is of an agreeable white colour, possessing considerable hardness and lustre. Its specific gravity is about 8.3, which increases with hammering. It is said to be capable of being hammered into sheets not thinner than $\frac{1}{16}$ of an inch. It is now generally believed to be magnetic, like iron. It does not fuse at a temperature less than 160° of Wedgewood. It possesses the valuable property of not being changed by exposure to the air, nor by immersion in water, at the common temperature. When, however, it is exposed to a tolerable heat, it becomes tarnished, and ultimately covered with oxyd. A much stronger heat sets this oxygen free, as is the case with the noble metals.

The oxyds of nickel at present known are two, namely, the grey and the black. Chemists are at present divided in opinion whether the green oxyd be the first or second oxyd. Dalton seems to be uncertain as to this point, the atom of oxygen being 7. And since the analysis of Richter gives 78 of metal to 22 of oxygen, we shall have, considering the

grey oxyd the first oxyd, $\frac{x}{7} = \frac{78}{22}$, and $x = \frac{78 \times 7}{22} = 24.81$, the weight of the atom of nickel. If it be considered as the second oxyd, then $\frac{x}{14} = \frac{78}{22}$, and $x = 49.62$, the weight of the atom of nickel. These numbers are so near 25 and 50, that Dalton has given with doubt 25 or 50 for the atom of nickel. Sir Humphrey Davy thinks the grey oxyd the second oxyd, from the number he gives for nickel agreeing also with the sulphuret. We have, therefore, good ground for stating the weight of an atom of nickel at 50. From these data the first oxyd will consist of 50 to 7, or in the 100, there is 87.7 nickel, and 12.3 oxygen. The second, 50 to 14, or 100 will give 78.1 nickel, and 21.9 oxygen. The

third, or black oxyd, will be 50 nickel to 21 oxygen, or in 100, there will be 70 of nickel, and 30 of oxygen.

The second oxyd is obtained by dissolving nickel in nitric acid, and precipitating the oxyd by means of potash. This precipitate is not the pure oxyd, but an hydrated oxyd, containing, according to Sir Humphrey Davy, $\frac{1}{4}$ th its weight of water. When this hydrat is heated to ignition, the water is separated, leaving the grey oxyd. When the oxymuriatic acid gas is passed through water mixed with the latter oxyd, it becomes converted into the black oxyd.

Nickel combines with sulphur. We are indebted to Mr. E. Davy for the proportions of its combination with sulphur, which he states at 34 sulphur to 66 nickel. This sulphuret must be considered as 2 atoms of sulphur, 2×13

to 1, of nickel, 50, for $\frac{50 + 26}{26} = \frac{100}{34.2}$, or 34.2 oxygen to 65.8 nickel. This very strongly confirms the truth of the number 50 for the weight of the atom of this metal. From the same authority there appears to be another sulphuret, formed by heating the grey oxyd with sulphur, consisting of 56.5 nickel, and 43.5 oxygen. This will be 3×13 to 50, which gives 43.8 sulphur, and 56.2 nickel. Nothing can be more satisfactory than this almost exact agreement between theory and practice. The first sulphuret will be 13 to 50, or in 100, 20.6 sulphur, and 79.4 nickel. According to the authority of Thenard, phosphorus combines with nickel in the proportions of 17 phosphorus to 83 of nickel. Theory would give the first phosphuret 50 to 9, or *per cent.* 15.3 phosphorus and 84.7 nickel. The second sulphuret will be 50 to 2×9 , or *per cent.* 73.5 nickel, and 26.5 phosphorus. The combination of nickel with hydrogen, nitrogen, carbon, and the base of the boracic acid, is not known. It forms alloys with some of the metals, but, these compounds have been little examined. Since nickel is a malleable metal, and difficult of fusion, some fusible alloy with it might be of importance. Its alloy with gold was tried by Mr. Hatchett in the proportions of 11 gold to 1 of nickel, which was brittle, and of the colour of brass. Sir H. Davy speaks highly of its alloy with iron: its colour approaches silver as the nickel prevails, while the malleability of the iron is not impaired. It is also less liable to rust than iron. The same author observes that iron in meteoric stones is alloyed with nickel from 1.5 to 17 *per cent.* of the latter

Salts of Nickel, or the Combination of its Oxyds with Acids:—The few facts of which we are in possession of combinations of this substance with acids, are not strictly to be relied upon, from the circumstance of the experiments being made upon impure nickel.

Sulphat of Nickel.—Sulphuric acid has little action upon nickel, but it dissolves its oxyd, forming a salt, the solution of which is of a beautiful green colour. By evaporation it affords prismatic crystals, which afterwards effloresce and become opaque. The composition of this salt has not been ascertained, but it may be inferred with some hope of truth, from the near coincidence of the other compounds of nickel with theory. The oxyd which unites with the acid is doubtless the grey; hence $34 + 50 + 14$ will constitute the salt, or 34 acid to 64 oxyd. This will give *per cent.* 34.7 acid, and 65.3 of base.

Nitrat of Nickel.—Nitric acid oxydates and dissolves nickel. The solution is of a green colour, and affords rhomboidal crystals. This salt is first deliquescent, and afterwards falls to powder, by losing its acid, the atom of nitric acid being 19; and since the soluble nitrats mostly contain two atoms of acid, it will be constituted by 2×19 acid to 64 of oxyd.

Muriat of Nickel.—The muriatic acid acts feebly upon nickel. With the aid of nitric acid, however, it becomes oxydated, and the muriatic acid dissolves it, forming a green solution, which at first crystallises in the form of rhomboidal prisms. These are soon acted upon by the air, and ultimately lose the acid, like the nitrat, the atom of muriatic acid being 22. This salt will consist of 22 acid, and 64 of base.

Phosphat of Nickel.—The phosphoric acid takes up a very small quantity of the oxyd of nickel, and hence is perhaps almost an insoluble salt. Hence the best way of forming it will be by adding phosphat of soda to nitrat of nickel. It will be formed by 23 of acid, and 64 base.

Fluat of Nickel.—This salt is soluble, and affords green crystals. It will consist of 15 acid, and 64 base.

Borat of Nickel.—This salt is very little known. It may be formed by mixing borat of soda with nitrat of nickel.

Carbonat of Nickel.—This salt is mentioned by Bergman, who formed it by adding an alkaline carbonat to the nitrat of nickel. He found it to consist of 56.4 acid and water, and 43.6 of base.

Acetat of Nickel.—Oxyd of nickel dissolves in acetic acid, forming a soluble salt, which crystallises in a rhomboidal form, and of a green colour.

Oxalat of Nickel.—The oxalic acid slightly attacks nickel, with which it forms a green powder, from the salt being insoluble. It should be formed by adding oxalat of soda to a nitrat of nickel. The salt falls down in the form of green powder.

Tartrat of Nickel has not been examined.

Arseniat of Nickel.—This is a soluble salt, but little known.

Molybdat of Nickel.—This salt is in the form of white powder, and probably insoluble.

Sulphat of Nickel and Potash.—This is a triple salt, discovered by Proust. It is formed by adding potash to the sulphat of nickel. By evaporation it easily crystallises in the form of prisms of a beautiful green colour. It has a sweetish taste.

Sulphat of Nickel and Ammonia.—Using ammonia as the potash is used in the last salt, forms a triple salt of a green colour, affording flat prismatic crystals.

Sulphat of Nickel and Iron.—This salt is formed by adding nitrat of nickel to sulphat of iron, or by dissolving the two oxyds in sulphuric acid. It affords green crystals, which are efflorescent.

A triple salt is also formed by adding an excess of ammonia to nitrat of nickel, consisting of nitric acid united with oxyd of nickel and ammonia. It affords green coloured crystals. This salt has the peculiar property of being decomposed by the alkalies, at least the oxyd is not precipitated. This property is of some importance for separating nickel from other metals. The metal is, however, precipitated by the hydro-sulphurets. For the principles on which the numbers representing the relative weights of the atoms of bodies are calculated, see *PROPORTION of Chemical Compounds*

Nitrats

NITRATS, in *Chemistry*, that genus of salts formed by the nitric acid with the different saline bases. The great facility with which the nitric acid is decomposed by the different inflammable bodies, is the cause of the marked character of detonation possessed by these compounds. The heat and light furnished during the detonation of the nitrats with inflammable bodies, as in the case of gunpowder, has been used as a successful argument against the Lavoisierian doctrine of combustion. If the oxygen be the source of the light and heat, and that only when it passes from the elastic to the solid or liquid form, it will be evident, that cold ought to be produced from the detonation of the nitrats. It is now, however, pretty generally admitted, that bodies do not give out caloric in the ratio of their condensation, but in proportion to the change of specific heat during the chemical change. It is therefore highly probable, that no great quantity of heat is given out during the combination of nitrogen with oxygen to form nitric acid. It must also be admitted, that the inflammable bodies themselves give out a quantity of caloric during the detonation with nitre. A similar conclusion must be drawn in the action between oxymuriat of potash and the inflammable bodies.

The greatest proportion of the soluble nitrats contain 2 atoms of acid to 1 of base, so that instead of considering the acid as 19, the weight of 1 atom, hydrogen being 1, it will be generally found 38. Those salts, which have been called sub-nitrats, are generally nitrats, in which the acid is 19. We shall now give an account of some of the nitrats that have been omitted in their proper places, and refer to others under their respective bases. Of these the most important is the *nitrat* of POTASH; which see.

NITRAT of Alumine. This salt is prepared by dissolving alumine in nitric acid, and evaporating the solution till the salt crystallises. In this salt there is always an excess of acid, and it is therefore sometimes reckoned a super-nitrat. It crystallises with great difficulty in thin soft plates, which have but little brilliancy. It has an acid and also an astringent taste. Its specific gravity, according to Hassenfratz, is 1.645. It is very soluble in water, and when the fluid is evaporated, it is converted into a glutinous mass

of the consistence of honey. It often allumes on cooling the form of a jelly. When exposed to the air, it very soon attracts moisture and deliquesces. When heated, the acid is disengaged with great facility, and the earth remains behind.

NITRAT of Ammonia. This salt was formerly distinguished by the names of *nitrum semivolatile*, and *nitrum flammans*. Berthollet examined it in the course of his experiments on the component parts of nitric acid, and sir Humphrey Davy, in his researches, has added considerably to our knowledge of its composition and decomposition. It may be prepared by dissolving carbonat of ammonia in diluted nitric acid, and evaporating the solution till the salt crystallises. The appearance of this salt varies much according to the temperature at which its solution is evaporated. In a heat of from 70° to 100°, and by slow cooling, it is obtained in six-sided prisms, terminated by long six-sided pyramids. When the solution is evaporated at the temperature, of boiling water, or 212°, the crystals are channelled and have a fibrous texture, or they are formed of long elastic threads. When dried in a heat of about 300°, it assumes the form of a white and very compact mass. These differences are unquestionably owing to different proportions of water of crystallization, which the salt contains. Nitrat of ammonia has a very acrid, bitter, and disagreeable taste. Its specific gravity is, according to Hassenfratz, in the *Annales de Chimie*, 1.579. At the temperature of 60° it is soluble in two parts of water, and it dissolves in half its weight of boiling water. When exposed to the air, nitrat of ammonia soon attracts moisture and deliquesces. When it is heated in the state of crystals, it becomes fluid at a temperature below 300°, and at from 360° to 400° it boils without decomposition; but when heated to 450°, or higher, it is gradually decomposed without losing its water of crystallization. When this salt is decomposed in a temperature not exceeding 500°, it is wholly converted into nitrous oxyd and water. From the experiments of sir H. Davy these products are in about the proportion of four parts of gas to three of water. When exposed to a heat of 600°, and higher, it explodes, and is

totally decomposed, being converted into nitrous gas, nitrous acid, water and azotic gas. Hence its name among the older chemists, *nitrum flammans*. Its constituent parts, according to Sir H. Davy, are

Acid	-	69.5	72.5	74.5
Base	-	18.4	19.3	19.8
Water	-	12.1	8.2	5.7

100	100	100
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In the first of these analyses the salt was prismatic; in the second it was fibrous; and in the third it was compact. The chief use of this salt is for yielding Nitrous Oxide; which see.

NITRAT of Barytes is usually prepared by dissolving native carbonat of barytes in nitric acid, or by decomposing sulphuret of barytes by means of nitric acid, and evaporating the filtered solution till the nitrat crystallises. Its crystals are regular octahedrons, and they often adhere to each other in the form of stars. Sometimes it is obtained in small brilliant plates. Its specific gravity is 29.2 nearly. It is very easily reduced to powder. Its taste is hot, acrid, and austere. It is soluble in 12 parts of water at the temperature of 60°, and in about three or four parts of boiling water. As the solution cools, the salt may be obtained in crystals. It is scarcely at all altered by exposure to the air. When thrown on burning coals it decrepitates, undergoes a kind of fusion, and then becomes dry. When strongly heated in a crucible, the whole acid is gradually driven off, and the barytes remains pure. It detonates less violently with combustibles than most of the nitrats. The constituents are given by Fourcroy and Vauquelin, in the *Annales de Chimie*, as follows:

Acid	-	-	38
Base	-	-	50
Water	-	-	12
			100

NITRAT of Glucine. See GLYCINE.

NITRAT of Lime. See LIME.

NITRAT of Magnesia. See MAGNESIA.

NITRAT of Magnesia and Ammonia was first described by Fourcroy in 1790, and is prepared by mixing together the solutions of nitrat of ammonia and nitrat of magnesia, or by decomposing either of these salts in part by the base of the other. When the two salts are mixed together, the nitrat of ammonia and magnesia gradually precipitates in crystals. These crystals are in the form of fine prisms; they have a bitter acrid ammoniacal taste; are soluble in about 11 parts of water at the heat of 60°, and in less as the temperature is higher. When exposed to the air, they gradually attract moisture, but more slowly than either of their component parts. The phenomena, which this compound exhibits when heated, are similar to those which its component parts exhibit in like circumstances. According to Fourcroy it is composed of

78 parts of nitrat of magnesia,
22 ————— ammonia.

NITRAT of Silver, in the *Materia Medica*. See SILVER.

NITRAT of Soda. See SODA.

NITRAT of Strontian. See STRONTIAN.

NITRAT of Yttria. See YTTRIA.

NITRAT of Zirconia. See ZIRCONIA.

NITRAT of Ammonia, in *Agriculture*, a neutral saline substance formed by the combination of the nitric acid and

ammonia, or volatile alkali. This substance cannot be obtained in sufficient proportions for the purposes of agriculture, but is useful in the analysis of soils.

NITRAT of Iron, a salt formed by the union of nitric acid with iron, but is a salt rarely presented by nature: its properties or effects, as they may apply to agriculture, are not, Lord Dundonald says, worthy of much observation.

NITRAT of Lime, is an earthy salt which consists of the nitric acid and lime. It is found in the mother-earth of nitre manufactories, on old walls, and mixed with true native nitre in the kingdom of Naples. The purest is obtained by the artificial and direct combination of its constituent parts. And it is a saline substance, that is also found in the rubbish of old buildings, and in those materials from which saltpetre is extracted: viz. animal and vegetable matters, which, with a due proportion of calcareous earth, have undergone the putrefactive process, together with a subsequent, sufficiently long, exposure to atmospheric air. According to Dr. Home, it is likewise contained in what is commonly called hard-water, which, by his experiments, was found to promote the growth of plants in a much higher degree than soft-water. It is very soluble and deliquescent; it is decomposed by fixed alkalies, and forms therewith nitrat of potash or saltpetre, and nitrat of soda, or cubic nitre.

NITRAT of Magnesia, is an earthy salt, composed of the nitric acid and pure magnesia. It is found native in the mother-earth of nitre manufactories, and on walls. It has been obtained artificially by direct and indirect combination.

Lord Dundonald remarks that no agricultural experiments have yet been made with this compound; it is a very deliquescent and soluble salt; and there is reason to expect, that it will produce effects in promoting vegetation, similar to those which may result from the application of the nitrat of lime.

It is decomposed by alkalies and lime, and forms therewith nitrat of potash, nitrat of soda, and nitrat of lime.

NITRAT of Potash, a neutral salt, formed by the combination of nitric acid and potash, or the fixed vegetable alkali. It is found in the fissures of the lime-stone hills, near Molfetta, in the kingdom of Naples, in various waters, and even in rain: likewise in the fresh juices of many plants, such as the heliotrope, pellitory, tobacco, and others. It is produced spontaneously wherever its alkaline basis is exposed to a free current of air, and to the exhalations of putrescent vegetable and animal matter; as on damp walls, rubbish, the ordure of stables, dunghills, &c. In Spain, the East Indies, and near Lima, it is generated upon commons and uncultivated ground; and it is even asserted that in the southern regions of Spain, saltpetre is found in the dust of the high roads. Lord Dundonald, in his treatise on the Connection of Agriculture with Chemistry, states "that it is constituted by the putrefaction and complete decomposition of animal and vegetable substances, when mixed with calcareous matter and wood ashes." It is found to promote vegetation, but is too expensive to be used as a manure for land.

NITRAT of Soda, a very soluble substance, formed from the combination of the nitric acid and the mineral alkali, or soda, which, on account of the figure of its crystals, has obtained the name of cubic, or more properly, of rhomboidal nitre. Bergmann distinguishes it by the name of nitrated soda, and modern chemists by that of nitrat of soda. It has not hitherto been found in a native state, but is always produced, either directly or indirectly, by the artificial combination of its constituent parts. "Lord Dundo-

nald supposes it capable of promoting vegetation in an equal degree with the nitrat of potash."

NITRE, in *Chemistry*, the *Materia Medica*, &c. See *Nitrat of Potash*, under **POTASH**.

NITRE, in *Agriculture*, a term formerly applied to a salt extracted in Persia and the East Indies, from certain earths that lie on the sides of hills; and artificially produced, in some parts of Europe, from animal and vegetable matters rotted together (with the addition of lime and ashes), and exposed for a length of time to the air, without the access of which nitre is never generated.

It was formerly supposed to have much influence in the business of vegetation. See *NITRAT of Potash*.

NITRE, *Alkalised*, is the fixed alkali remaining after the nitrous acid has been destroyed by its detonation with any inflammable matter. This alkali is generally called *fixed nitre*.

NITRE, *Ammoniacal*, is a neutral salt resulting from the combination of the nitrous acid, to the point of saturation, with volatile alkali. The acid, in the most concentrated state in which it is commonly met with, saturates about five-sixths its weight of vegetable fixed alkali.

NITRE, *Antimoniated*. See **ANTIMONY**.

NITRE, *Calcareous*, is a neutral salt, compounded of the nitrous acid combined to saturation with a calcareous earth; and generally called *nitre with an earthy basis*. This salt is very deliquescent, but incapable of a true crystallization. It has a poignant, acrid, and bitter taste. See **NITRUM Calcareum**.

NITRE, *Clyffus of*. See **CLYSSUS**.

NITRE, *Crystals of*. See **CRYSTAL**.

NITRE, *Cubic*, or *Quadrangular*, is a neutral salt, formed by the nitrous acid when saturated with mineral alkali. This crystallises not into a prismatic but a cubical figure, and sometimes into parallelepipeds, with rhomboidal faces. It is inferior to ordinary nitre, and never used.

NITRE, *Decoction of*, is prepared by boiling half an ounce of nitre, and two ounces of fine sugar, with a scruple of cochineal as a colouring material, in $2\frac{1}{2}$ pints of water, till half a pint is wasted, and after standing to settle, the clear purplish-red liquor is poured off for use.

NITRE, *Diaphoretic, of Antimony*. See **ANTIMONY**.

NITRE, *Fixed by Arsenic*, is the alkali of nitre, the acid of which has been expelled in an open fire by means of arsenic, of which some portion is retained by the alkali. This may be employed as a flux, as it greatly assists vitrification.

NITRE, *Fixed by Coals*. See **FIXED NITRE**.

NITRE, *Fixed by Metals*, is the alkali of nitre separated from its acid, and mixed with the earth of the calcined metals.

NITRE, *Fixed by Tartar*, is the alkali of nitre and that of tartar mixed together by means of detonation. This is called the *white flux*.

NITRE, *Glauber's Spirit of*. See **SPIRIT**, and **NITRIC Acid**.

NITRES, *Metallic*, a general denomination that comprehends all neutral salts composed of the nitrous acid united with a metallic substance; the several kinds of which may be thus distinguished, viz. *nitre of silver*, called *lunar crystals*, *nitre of lead*, *nitre of mercury*, &c. The acid acts in general powerfully upon all metallic substances, but with remarkable differences, depending on the peculiar natures of the metals. It dissolves zinc, iron, copper, bismuth, lead, mercury, and silver, the most readily of all the acids; tin it dissolves imperfectly; regulus of antimony it only corrodes; gold and platinum cannot be dissolved by nitrous acid alone, without the concurrence of marine acid.

NITRE, *Nitred*. See **NITRUM Nitratum**.

NITRE, *Purified*. See **NITRUM Purificatum**.

NITRE, *Spirit of*. See **SPIRIT**.

NITRE, *Troches of*, are made by grinding one part of the purified salt with three parts of fine sugar, and making up the mixture with mucilage of gum tragacanth.

NITRE, *Vegetating*. See **NITRUM Vegetans**.

NITRE, *Vitriolated*. See **NITRUM Vitriolatum**.

NITRIC Acid, in *Chemistry*, so called by the French chemists in 1787, is a compound of great value in the hands of the analytical chemist. Although this acid may be formed synthetically, in very small quantity, by passing electric sparks, in quick succession, through a mixture of oxygen and nitrogen gases, it is, for all useful purposes, obtained from nitre (nitrat of potash). It appears first to have been procured from this substance by Raymond Lully in the 13th century, by distilling it from a mixture of nitre and clay. This method is still practised in some manufactories, but it is more generally procured by decomposing the nitre by means of sulphuric acid, a process first discovered by Glauber.

Into a glass retort put two parts of nitre and one of sulphuric acid, of the specific gravity of 1.85. A capacious quelled receiver is now to be luted to the retort: the heat of a lamp or a sand-bath must then be gently applied. The nitric acid soon begins to be evolved, which condenses in the neck of the retort, and runs into the receiver, of a pale yellow colour. As the heat is increased, yellow fumes arise, and the vapour becomes more difficultly condensed. In this stage of the process some of the acid is decomposed into nitrous gas and oxygen gas. These elastic fluids render the quelled receiver, or a tube of safety, highly necessary. The last portion of acid is not brought off till the heat has been raised almost to redness.

The liquid obtained by this process was called by the old chemists spirit of nitre, and aquafortis. It is of a deep yellow or orange colour, and consists, if the materials employed be pure, of nitric acid mixed with nitrous gas, to which it owes its yellow colour; as when this gas is expelled by heat the acid becomes colourless as water.

In the large way, and for the purposes of the arts, this acid is made in extremely thick cast iron or earthen retorts, to which an earthen head is adapted, and connected with a range of proper condensers. The strength of the acid is varied by putting more or less water in the receivers. The nitric acid, thus made, generally contains sulphuric acid, and muriatic acid from the impurity of the nitrat employed. If the former, a solution of nitrat of barytes will occasion a white precipitate: if the latter, nitrat of silver will render it milky. The sulphuric acid may be separated by a second distillation from very pure nitre, equal in weight to an eighth of that originally employed; or by precipitating with nitrat of barytes, decanting the clear liquid, and distilling it. The muriatic acid may be separated by proceeding in the same way with nitrat of silver, or with litharge, decanting the clear liquor, and re-distilling it, leaving an eighth or tenth part in the retort. The acid for the last process should be condensed as much as possible, and the re-distillation conducted very slowly; and if it be stopped when half is come over, beautiful crystals of muriat of lead will be obtained on cooling the remainder, if litharge be used. Other methods are mentioned for the obtaining aquafortis or nitric acid. The following, which differs but little from that of Glauber, is given by sir Humphrey Davy in his *Elements of Chemical Philosophy*. "It is," he says, "procured, for the purpose of chemistry, by the distillation of nitre and oil of vitriol:

about two parts of nitre should be used to one part of oil of vitriol, and the retort heated in a sand-bath connected with a receiver kept cool by moistened cloths. This acid, thus obtained, is usually coloured, but becomes pale by exposure to air. If the nitre be dry, its specific gravity is from 1.52 to 1.55. This substance acts with great violence on all metals anciently known, excepting gold and platina, and it causes volatile oils to inflame. When it is passed through a porcelain tube heated to redness, oxygen is given off, and nitrous acid gas; and the same effect is produced upon the residual acid, as if it had been mixed with water; so that it is proved to be composed of nitrous acid gas, oxygen of water: and four in volume of nitrous gas, and two of oxygen gas condensed in water, I find absorb one in volume of oxygen to become nitric acid." He further adds, that from his own experiments, compared with those of Kirwan, Wenzel, and Berthollet, he thinks that the strongest acids contain from 14 to 15 per cent. of water, and, according to the principles of the French nomenclature, they ought to be called nitro-nitric acids. Aquafortis, or hydro-nitric acid, when its specific gravity is below 1.4, strengthens by being boiled: when stronger than 1.45, it becomes weaker by boiling.

The nitre of commerce frequently contains some muriatic salts, which being decomposed by the sulphuric, in common with the nitre, the muriatic acid comes over mixed with the nitric. If an excess of sulphuric acid be employed, and the heat be very great, the latter, more or less, is frequently distilled over, so that nitric acid is often contaminated with sulphuric and muriatic acids. The presence of the muriatic acid may be best avoided by carefully crystallizing the nitre to be employed. If at last it should still contain a little muriatic acid, it may be separated by nitrat of silver. The sulphuric acid may be separated by re-distilling from a litharge, or barytes sufficient to saturate all the sulphuric acid. After the nitrous gas has been expelled by heat, the acid may be deemed pure. In this state it is perfectly colourless, and of a strong acid taste, which, when diluted with water, is not unpleasant. It should be kept in a bottle coated on the outside with black varnish, or in a dark place. When it is exposed to the light, oxygen gas is disengaged, and the nitrous gas which is liberated tinges it of a yellow colour.

When exposed to the air it appears to exhale white fumes. This is occasioned by the great attraction of the acid for the moisture of the atmosphere.

To all animal substances it gives a beautiful yellow tinge.

The strongest acid yet produced is not of greater specific gravity than 1.62. Mr. Dalton informs us, that when its specific gravity is 1.42, it boils at 248° of Fahrenheit. If it be stronger, the acid is distilled off; and if weaker, the water, till it comes to the above maximum. It corrodes animal and vegetable substances very speedily, and the latter in the greatest degree. The yellow colour it gives to them, excepting substances containing albumen, is not produced but when the acid is very strong, and assisted by heat. If it be added to the essential oils, they speedily inflame, leaving behind a spongy coal. When it is poured upon powdered charcoal, very dry, it takes fire. The same effects take place with sulphur and phosphorus, at a certain temperature.

It is decomposed by all the metals, excepting gold, platina, and titanium: hence it is an important agent in chemistry for oxydating most of these substances. Many of the metals, such as zinc, iron, tin, &c. take the whole of the oxygen from it, while nitrogen alone is disengaged. Others of the metals, such as silver, mercury, copper, &c.

deprive it of only one atom of oxygen, the nitrous gas being set free, producing red fumes with the presence of oxygen. When it is poured on zinc, tin, or bismuth, in a state of fusion, inflammation takes place. The same effect takes place in the cold when the metals are in fine powder.

Nitric acid, as has been described, is not to be regarded as the real acid, but a compound of real acid and water. The determination of real acid, in a given quantity of the liquid, has much engaged the attention of chemists. We are indebted to Kirwan, Davy, Berthollet, and Dalton, for researches on this subject. The experiments of the first and last of these chemists appear to come nearest the truth.

Mr. Kirwan deprived some carbonat of soda of its water of crystallization: 367 grains of a solution of this salt contained 50.05 grains. This was saturated with 147 grains of nitric acid, of the specific gravity of 1.2754, equal, as he had ascertained, to 67.179 grains, of the specific gravity 1.5543, which he made his standard. The carbonic acid evolved by adding nitric acid was 14 grains. To this solution he added 939 grains of water, which reduced it to the specific gravity 1.0401, at the temperature of 58°.5, the whole solution weighing 1439 grains. He next prepared a solution of nitrat of soda, of the specific gravity of 1.0401, and found that the salt, in 1439 grains of this solution, was

$\frac{1}{16.901}$ of the whole; therefore $\frac{1439}{16.901} = 85.142$ grains of nitrat of soda. Now, the $50.05 - 14 = 36.05$ gr. is the weight of the alkali. The acid, therefore, will be $85.142 - 36.05 = 49.092$ grains; but the acid of 1.5543 weighed 67.179 grains; consequently $67.179 - 49.092 = 18.087$ will be the water contained in 67.179 of acid, of 1.5543 specific gravity, which is equal to 26.9 per cent. Hence 100 parts of nitric acid of 1.5543, consists of 73.1 of real acid, and 26.9 of water.

Dalton has made a number of similar experiments, which strongly confirm the conclusions of Kirwan, the greatest difference between them being no more than 1.4 per cent. in the quantity of real acid. The following is a table given by Dalton. The column of real acid is taken from Kirwan, with trifling corrections: in which he has also given a column for the quantity of real acid by measure, and another shewing the number of atoms of acid and water.

Atoms.	Acid per cent. by Measure.	Acid per cent. by Weight.	Specific Gravity.	Boiling Point.
Acid. Water.				
1 + 0	17.5	100	1.75	30°
2 + 1	13.4	82.7	1.62	100
1 + 1	11.2	72.5	1.54	175
	10.2	68.5	1.50	210
	84.7	58.4	1.45	240
1 + 2	77.2	54.4	1.42	248
	71.7	51.2	1.40	247
1 + 3	59.8	44.3	1.35	242
1 + 4	48.6	37.4	1.30	236
1 + 5	40.7	32.3	1.26	232
1 + 6	34.8	28.5	1.22	229
1 + 7	30.5	25.4	1.20	226
1 + 8	27.1	23	1.18	223
1 + 9	24.6	21	1.17	221
1 + 10	22.4	19.3	1.16	220
1 + 11	20.5	17.8	1.15	219
1 + 12	18.9	16.6	1.14	219

The first column of this table shews the number of atoms of acid and water, in which it appears, that when the compound is 1 atom of acid to 1 of water, the liquid acid contains 72.5 of real acid, and 27.5 of water by weight, and the same by measure will be 112 acid: this last is governed by the specific gravity, which is 1.54. The boiling point of this strength being at 175° , it will be seen that the maximum of the boiling point is at 248° ; when the liquid acid consists of 1 atom of real acid to 2 of water, the specific gravity being 1.42, and the real acid 54.4 per cent. The acid, free from water, if its existence in the liquid form be possible, Mr. Dalton supposes would be as volatile as æther. It appears that the acid of 1.42 is the best strength to remain permanent, since, according to the experiments of this ingenious chemist, the acid and water are so nearly balanced in their affinities as to evaporate together. The acid or the water will therefore be apt to evaporate, as the real acid or water may be in excess above this point, which may be denominated the point of mutual saturation.

The acid of this strength has very curious properties, on which Dalton makes some ingenious observations. Proust has stated, that an acid of the strength of 1.48 gives no more effervescence with tin than it does with sand. When metals, which produce ammonia, are acted upon by nitric acid; these, I suppose, are such as decompose both the water and acid, taking all the oxygen from both. The metal, under this circumstance, combines with 3 atoms of oxygen, while the nitrogen and the hydrogen form ammonia. If the acid consisted of 1 of real acid to 2 of water, an atom of water would be set free, which would dilute the remaining acid, and thus facilitate the process. If, however, the acid and water were as 2 to 3, then an atom of nitric acid, and an atom of water, would be afforded to the atom of ammonia, forming an atom of nitrat of ammonia. The remaining acid and water would just be reduced to 1 of acid to 2 of water. At this point, and below it, effervescence would take place; but in the instance with 2 of acid to 3 of water, all the products will be disposed of in forming nitrat of ammonia, and reducing the acid to the strength of 1 of acid to 2 of water, during which change no effervescence will take place. This view of the subject is very ingenious, and fully explains the phenomena attendant on the oxidation of those metals which cause the formation of ammonia.

The acid of 1 of acid to 3 of water, has no striking properties. That which consists of 1 to 4, Mr. Dalton is of opinion, is that which freezes at -2° of Fahrenheit. Mr. Dalton, and previous to him, sir Humphrey Davy, have attempted to procure nitric acid in the gaseous form, by combining nitric oxyd (nitrous gas) with oxygen, but their results have not been attended with success. This appears to arise from the uncertainty in the combination of nitric oxyd gas with oxygen gas, especially when water is not present. It appears, from the experiments of Mr. Dalton, that nitric oxyd will combine with oxygen in any proportions between 1.3 and 3.6 of the oxyd to 1 of oxygen. This apparent anomaly to the doctrine of definite proportion is very ingeniously explained by the above-mentioned chemist. When the nitric oxyd is to oxygen as 3.6 to 1, the oxygen combines with one-half of the nitric oxyd, forming nitric acid, which combines afterwards with the other half to form nitrous acid, or the fuming and coloured nitric acid. When, on the other hand, 1 of oxygen combines with 1.3 of nitrous oxyd, in which the minimum of the latter exists, a compound is formed, which, according to the opinion of Mr. Dalton, consists of 1 atom of nitrogen with

3 of oxygen, and which he has denominated the oxynitric acid. The first of these combinations is favoured by using a vessel which gives a short column of great diameter, and in which the change is quick. The second combination, in which the oxygen is in excess, is facilitated by the change being slow, which is effected by using a long tube of small diameter. A tube of an intermediate size being employed when the gases are 1 of oxygen to 1.8 of nitric oxyd by measure, the nitric acid will be formed by the union of the two gases. It is the opinion of this distinguished chemist, that if the gases, even in exact proportions to form nitric acid, be mixed in a dry vessel, that all the compounds, namely, nitrous acid, nitric acid, and oxynitric acid, may exist, which, when water is introduced, may so act upon each other, as to form nitric acid. These facts, with the reasoning resulting from the same, seem to baffle all attempts to obtain nitric acid in a free state. Mr. Dalton, after much care and attention, has given the means to determine the component parts of the nitric acid. If, as he seems fully to have established, the atom of nitrogen be 5, and the acid be constituted by 1 atom of nitrogen to 2 of oxygen, the proportions will be 14 of oxygen to 5 of nitrogen, and the weight of the atom of acid will be 19. For the colouring of fuming nitric acid, see *NITROUS Acid*; see also *NITRIC Oxyd*, and *NITROUS Oxyd*. The combinations of nitric acid with the different saline bases, are called *nitrats*.

NITRIC, and NITROUS Acid, in the *Materia Medica*. The nitric acid of the London Pharmacopeia is prepared by mixing nitrat of potash dried and sulphuric acid, of each two pounds, in a glass retort; and distilling the nitric acid from a sand-bath, until red vapours are produced; then add an ounce of dried nitrat of potash, and re-distil the acid in a similar manner. The specific gravity of this acid is to that of distilled water as 1.500 to 1.000. If a piece of lime-stone be immersed in a fluid-ounce of it diluted with water, seven drams ought to be dissolved. According to the directions of the Edinburgh Pharmacopeia, any quantity of nitrous acid is put into a retort, and having fitted a receiver, a very gentle heat is applied until the reddest part shall have passed over, and the acid which remains in the retort have become nitric acid. The nitrous acid of the Edinburgh Pharmacopeia is prepared by pouring sixteen ounces of sulphuric acid upon two pounds of bruised nitrat of potash in a glass retort, and distilling from a sand-bath, with a gradually augmented heat, until the iron pot becomes obscurely red-hot. The specific gravity of this acid is to that of distilled water as 1.550 to 1.000. The Dublin Pharmacopeia orders six pounds of nitrat of kali to be mixed with four pounds by weight of sulphuric acid, and then distilled until the residue becomes dry. The specific gravity of this acid is to that of distilled water as 1.500 to 1.000.

In performing these operations, it is advisable to use Woulfe's apparatus, or a range of two or three globular receivers, the last of which should contain a small portion of water. In order to prevent the nitrous oxyd from combining with the condensed acid in the receiver, deepening its colour, and giving it that form which constitutes nitrous acid, the London College orders a large portion of sulphuric acid to be employed, which serves to contribute a sufficient portion of water for preserving the constitution of the nitric acid; for, although a large proportion of this acid be obtained by following the directions of the London formula, yet it is actually weaker than that which is obtained either by the Edinburgh or the Dublin processes. The Edinburgh College orders the acid to be kept in this form; and as a medical agent it answers the same purposes as the colourless acid; for, when both are diluted with water, they have

the same appearance, and are brought to the same state, the addition of the water expelling completely the nitrous oxyd, which is loosely united with the nitric acid to form the nitrous. The quantity of acid obtained is about half the weight of the nitrat employed: and the residue is a white, spongy, saline cake of sulphat of potash, with an excess of sulphuric acid, which may be dissolved out of the retort by hot water. By the London process, the nitric acid is at first obtained tolerably free from nitrous oxyd; but in general the re-distillation will be found necessary. In the expulsion of the nitric oxyd, to change the nitrous into nitric acid, according to the directions of the Edinburgh College, a portion of the acid is carried over with the gas, as nitrous acid vapour: this should not be wasted, but be condensed by a small portion of water being put into the receiver, and thus form a diluted acid. Mr. Murray (Mat. Med.) justly observes, that the heat of a water-bath is best adapted for this operation, being sufficient for the purpose, and not too high to produce the decomposition of the acid. A completely colourless acid, however, is not obtained, unless the acid be re-distilled from a small portion of black oxyd of manganese; but this is not necessary for medical purposes. The contaminations of nitric acid by muriatic or sulphuric acid do not affect its medicinal virtues.

Nitrous acid, as the term is understood in the Edinburgh Pharmacopeia, is a yellow or orange-coloured fluid, emitting, when exposed to the air, deep orange-coloured extremely suffocating fumes. With regard to its chemical affinities and other qualities, it agrees in every respect with nitric acid. It consists of nitric oxyd loosely combined with nitric acid and water.

Nitric acid is a colourless, or very pale yellow, limpid fluid, emitting, when exposed to the air, white suffocating vapours, and possessing strong acid properties. It is highly corrosive, and tinges the skin yellow, which remains till the epidermis is peeled off. It unites with water in every proportion, and while mixing heat is evolved. See the articles *NITRIC* and *NITROUS Acid*, *supra*.

Strong fluid nitric acid is used only for pharmaceutical purposes: except when extricated in the form of vapour, it is employed for destroying contagion. It is less powerful than the oxymuriatic acid, but is more generally useful, as it can be extricated in the chambers of the sick without proving deleterious to animal life. For this purpose, f3ij of sulphuric acid may be poured over ʒiv of coarsely powdered nitre in a china cup, and placed in a pipkin of hot sand. This quantity is sufficient for fumigating a room that is ten feet square; and where a larger portion is required, it is more advisable to multiply the number of pipkins than to put a larger quantity of the materials into one vessel. The official preparations of nitric acid are the following, *viz.* *Acidum nitricum dilutum*, L. E. D.; *Oxydum antimonii*, L.; *Argenti nitras*, L. D.; *Liquor ferri alkalmi*, L.; *Ung. hydrargyri nitratis*, L. E. D.; *Hydrargyri nitricum oxydum*, L.; *Spiritus ætheris nitrici*, L. E. D.; *Unguentum acidi nitrosi*, E. D.

The diluted nitric acid, L., is prepared by mixing a fluid-ounce of nitric acid with nine fluid-ounces of distilled water. For that of E. take equal weights of nitrous acid and mix them, avoiding the noxious vapours. For that of D. take of nitrous acid and distilled water of each one pound. The specific gravity of this mixture is to that of distilled water as 1280 to 1000. When the diluted acid is prepared according to the directions of the London College, f3i contains about grs. x of nitric acid, of 1.500 specific gravity, while the same measure of the

same acid, prepared after the Edinburgh and Dublin, and the former London formulæ, contains grs. xxxv of the same acid; a difference, which, as it may lead to errors in practice, is to be regretted.

Nitric acid is tonic and antiseptic. When largely diluted with water, it forms an agreeable and useful beverage in fevers, particularly of the typhoid type. In larger doses, less diluted, it has been administered with effect in chronic hepatitis, even when dropsy has supervened; and it has also been serviceable in restraining violent sickness, in dyspepsia, asthma, and the greater number of cachexiæ. From observations of Mr. Scott, published at Bombay in 1796, this acid excited attention as a remedy for syphilis; but after the most ample trials, by almost every practitioner of eminence in the country, its antisyphilitic powers have not been found to correspond to the accounts of those transmitted from India. Although it gives a temporary check to the progress of the disease, it does not permanently remove the symptoms; and, as Mr. Pearson justly observes, it would by no means be warrantable to substitute the nitrous (or nitric) acid in the place of mercury, for the cure of venereal complaints. It has been found, however, of considerable service when given at the same time with mercury, in old obstinate ulcerations of the legs, although no venereal taint could be suspected; and it is employed with benefit as a local stimulant in the form of lotion, in the proportion of f3ij of the acid to oʒ of water, for fœtid ulcers, attended with a thin ichorous discharge, and in caries of the bones. In India it is sometimes used in the form of a bath, and in this state produces the same effects as when it is taken internally. The dose of the diluted acid is from m x to m xxx in f3ij of water, given three or four times a day. Its official preparations are, *Aceti hydrargyri*, E. D.; *Submuriæ hydrargyri præcipitatus*, E. D.; *Submuriæ hydrargyri ammoniatus*, D.; *Oxydum hydrargyri cinereum*, E. D.; *Oxydum hydrargyri rubrum*, E. D. See *MERCURY*, Thomson's Lond. Dispensatory, 1811.

NITRIC Oxyd, in *Chemistry*. This substance, like the nitric acid, is a compound of nitrogen with oxygen: the former being formed of 1 atom of nitrogen to 2 of oxygen, the latter 1 to 1.

Several of the metals, as silver, mercury, and copper, when added to the nitric acid, deprive it of 1 atom of oxygen only. The remainder, which is 1 to 1, escapes in the form of gas. This gas has been formerly called nitrous gas; but, according to the present state of chemical nomenclature, it is called nitric oxyd.

To procure nitric oxyd, introduce small bits of copper into a gas bottle, or a small retort, upon which pour nitric acid of the specific gravity 1.2. Let the process go on a little, the mouth of the retort being under water, or mercury, before the gas is collected. This serves to displace the air of the retort. The gas, which is now obtained, will be colourless as common air. In this process, an atom of copper decomposes two atoms of nitric acid, taking an atom from each to form the second oxyd of copper. This oxyd then combines with two other atoms of acid, to form nitrat of copper. The two atoms of nitric oxyd, resulting from the decomposed acid, would be absorbed by the remaining acid, if a sufficient quantity were present; by which it would acquire, first, a yellow colour; a deep orange, as it increases; next, a green; and ultimately, a blueish tint. For the better observance of these shades of colour, silver should be employed instead of copper; since the solutions of copper in any acid are of green colour. When, however, the excess of acid is not great in producing nitric oxyd, a great proportion of this gas is evolved. For common pur-

poses, it may be collected over water, which absorbs only about $\frac{1}{10}$ th of its bulk: on some occasions, however, it is necessary to collect it over mercury.

Nitric oxyd may be separated from other gases, by means of solutions of iron with the black oxyd. The liquid, by agitation, soon absorbs all the nitric oxyd, without affecting any other gas that might exist with it. This furnishes an easy method of ascertaining the purity of nitric oxyd. The absorbed gas may be separated unchanged by heat.

When the nitric oxyd is mixed with oxygen, or is brought in contact with the atmosphere, red fumes immediately appear, which are of greater density than common air. This is called nitrous acid gas.

The specific gravity of nitric oxyd is to common air, according to Kirwan, as 1 to 1.19; but Davy, who is nearer the truth, makes it 1.102. If hydrogen be equal to 1, and 100 cubic inches weigh 2.5 grains, then the nitric oxyd will be 13, and 100 cubic inches of it will weigh 32.5 grains.

When a lighted taper, or sulphur in a state of inflammation, are immersed in this gas, the flame becomes extinguished; but phosphorus and charcoal, when once kindled, burn in it, and consequently deprive it of its oxygen.

Several of the metals, such as arsenic and zinc, when heated in this gas, deprive it of its oxygen; the residual gas being nitrogen.

Other bodies take away only part of its oxygen: of these are the alkaline sulphurets, the muriatic solution of tin, and several of the sulphats. For these facts we are indebted to sir Humphrey Davy. The resulting gas is the nitrous oxyd, which is composed, according to Dalton, of one atom of oxygen to two of nitrogen. In this process, an atom of nitric oxyd gas gives up an atom of oxygen, which combines with the decomposing body; while the deserted atom of nitrogen combines with an atom of nitrous gas, forming nitrous oxyd. This most clearly shews why the atom of nitrous oxyd should be heavier than an atom of nitric oxyd. The latter atom is constituted by 1 to 1 = 5 + 7 = 12; the former of 1 of oxygen to 2 of nitrogen, or 7 + 2 × 5 = 17. Sir Humphrey Davy, notwithstanding this corroborating fact, considers nitrous oxyd as 1 of oxygen to 1 of nitrogen; by doing which, the nitric acid is made to consist of 1 of nitrogen to 5 of oxygen; a thing very improbable between two bodies having so little affinity for each other.

When nitric oxyd is acted upon by electricity, an atom of oxygen is liberated from one atom of the gas, and given to another, till the whole is divided into nitric acid and nitrogen. In other words, one-half of the gas gives its oxygen to the other half. By this change, if the original

volume be 1, the resulting volume will be $\frac{1}{2} \times \frac{13}{12.125} =$

$\frac{13}{24.25}$, a little more than half.

When nitric oxyd is mixed with hydrogen, it does not explode by the electric spark. It is, however, said to detonate, when passed through a red-hot porcelain tube; the result being water and nitrogen. The relative volume of these gases, to produce this result, will be 13 of hydrogen and 12 of nitrogen.

We are indebted to Dr. Henry for the fact of nitric oxyd being decomposed by ammonia. For this purpose, the two gases are to be put into the strong tube, called Volta's eudiometer, and the electric spark passed through them. When the nitric oxyd is in excess, the result is nitrogen, water, and a little nitric acid; when the ammonia predominates, then nitrogen, water, and hydrogen are produced.

From the great facility with which the nitric oxyd combines with oxygen, it has been employed to ascertain the quantity of oxygen mixed with other gases. There is, however, some uncertainty in this method, in consequence of several compounds being formed by oxygen and nitric oxyd. Dalton recommends an excess of the latter to be used, in order to prevent the ambiguity above mentioned, and afterwards to take up the excess with a solution of the green sulphat of iron.

When nitric oxyd is mixed with oxymuriatic acid gas, a sudden decrease of volume takes place, from the muriatic acid and nitric acid being formed, both of which become liquid. This effect, however, does not take place, if the gases be perfectly dry, and the vessels free from moisture.

Since an atom of nitric oxyd consists of 1 of nitrogen to 1 of oxygen, the weight of its atom will be 5 + 7 = 12; the nitric acid, being 1 of nitrogen to 2 of oxygen, will be 5 + 2 × 7 = 17: hence the proportions of oxygen and nitric oxyd to form nitric acid will be 7 to 12. In mixing this with other gases, where mutual action takes place, the proportion by weight will be as the weights of their atoms. Their proportions by volume will be obtained, by multiplying the ratio of their weights by the united ratio of their specific gravities: the latter ratio will be easily expressed, by making the specific gravity of hydrogen gas unity. If, for instance, nitric oxyd be mixed with hydrogen, to be passed through a red-hot porcelain tube, the proportion by weight will be 12 of the oxyd to 1 of hydrogen, the re-

lative weights of their atoms, and $\frac{12}{1} \times \frac{1}{13} = \frac{12}{13}$, or 12

of nitric oxyd by measure to 13 of hydrogen. Ammonia

and nitric oxyd will be $\frac{6}{12} \times \frac{13}{7.5} = \frac{13}{15}$, or 13 by volume of ammonia to 15 of nitric acid.

Oblique arches

OBLIQUE Arches. Whenever high roads run oblique to the course of any river, rivulet, drain, or canal, necessary to be passed over by a bridge, the direction of the *former* is generally varied so as to be rectangular to the course of the *latter*; unless in small streams, over which, when their course is not made to suit the road, there are several instances of the construction of what are usually termed *skew-bridges*. These, with the exceptions which will be afterwards mentioned, have been built in the usual manner of laying each course of stones or bricks of the arch parallel to the line of the abutment, and bevelling off their ends, on each exterior face of the arch, in a line correspondent with the intended direction of the road over the bridge, as shewn in *fig. 1*. In this figure it is obvious, that so far as one abutment of the bridge extends beyond the rectangular line from the extremity of the other, such a portion of arch, *viz. a b*, has no support from the opposite abutment, unless what may be derived from the interlapping or breaking joint of the bricks or stones composing the arch; and from the goodness of the mortar, tending to cement them into one mass: therefore, accordingly as these circumstances have operated, and also in proportion to the smallness of the arch, in which the parapet covers a larger ratio of the unsupported part of it, the skew-bridges thus built have stood more or less firm, with an obliquity of 10° to 15° from a rectangle with the abutment; and in many instances, that portion of the arch has cracked or given way. These circumstances have prevented cautious builders from adopting this method; and induced them, in a few instances, to build the arch square to its abutments, and run the parapets oblique, to coincide with the line of road; leaving alternate triangles of the arch on the outside, which has a disagreeable appearance, and has seldom been used; therefore, in general, unless the courses of streams or canals were made rectangular to the road, the line of the latter has been altered so as to admit of a direct passage over the water, which upon high roads, when not curved for a considerable distance, is inconvenient if not dangerous; and particularly so to travellers in the night time; from which cause the skew-bridges described were, with all their imperfections, occasionally had recourse to; and the writer of this article has never heard of any alteration in their form prior to the year 1787. At this time he had the direction of the county of Kildare canal, a branch from the Grand Canal of Ireland to the town of Naas.

In the course of conducting the work, several of the directors of that canal were anxious to have the line of the roads unvaried; therefore our author was led to consider whether the usual imperfect method could not be set aside, by the substitution of one on sound principles; and it then occurred that its leading feature must be, that the joints of the voissairs, whether of brick or stone, should be rectangular with the face of the oblique arch, in place of parallel with its abutment; and, consequently, the bridges over the county of Kildare canal were made to suit the line of road, although the obliquity of one of them was carried to an extent beyond what he deemed eligible in practice, as will appear from the observations made on Finlay bridge, near the town of

Naas, which deviated 51° from a rectangle with the canal, and consequently formed the acute angle of 39° with its abutments. Its span, in that oblique direction, was 25 feet, and its pitch 5 feet 6 inches, or nearly $\frac{1}{3}$ ths of its span. The plan of this bridge is given in *fig. 2*, and in *fig. 3*, the elevation of its arch, more to shew the extent to which it has been carried than to recommend its propriety; principally because of the difficulty of forming the voissairs of the impost course; and also, because to retain the same breadth of roadway, the bridge must be enlarged as the secant of the angle of obliquity is to radius, *viz. as a b to a c*, which in the present instance is as 159° to 100° ; likewise, for general purposes, one breast-wall on each side must be considerably extended to coincide with its opposite one, or nearly so; also, the impost course must be ferrated, as shewn in the explanation of *fig. 8*; and as the lines, in which the beds of the voissairs run, are obviously spiral lines, it follows that the soffit of each stone must be curved in that direction, and likewise it must be twisted in its sommering, which, although not insuperable difficulties, are so in such a degree, as, combined with the indented form of the impost, to render it advisable to use bricks, both for the impost and arch, or at most to be contented with the use of stone only for the quoins and their necessary imposts, in the forming of which intelligent stone-cutters will be requisite, as will appear from *fig. 3*, where a part both of the intrados and extrados of the arch is shewn as viewed from an infinite distance, not being reduced in perspective. It is there apparent that the head of each voissair on that side of the arch where its face forms an acute angle with its abutment, must make an obtuse angle with its soffit, decreasing in their approach to the crown of the arch, and thenceforward becoming acute, and increasing as they advance to the other impost, where the face of the arch forms an obtuse angle with its abutment; therefore the different sides of the same voissair must form different angles of elevation or depression from the rectangle with its head.

A geometric mode of forming each voissair would be complicated, as will appear from the following diagrams, *viz.* let the lines *a b*, *b d*, and *d c*, in the diagram, *fig. 4*, include a portion of the space to be covered by the arch, *a b* and *c d* being the lines of its abutments: then let the distance intercepted between *d b*, and its parallel line *x y*, which likewise extends between the abutments, express the extent to be covered by any given number of the voissairs forming that portion of the soffit, suppose every alternate one:—let the circular arcs raised upon each of these lines express the elevation of the arch at each place respectively; *u* and *v* will then shew the crowns of their soffits. The line *t t*, drawn at right angles with the face of the arch, and with its respective extremities equidistant from the points *u* and *v*, will represent a joint on the soffit, which must necessarily be horizontal at its extremities; because equidistant from the crown of each arc, although on alternate sides; then if equal spaces on each side of the point, *t*, be set off on each respective arc, it will shew upon each where the joints of the same voissairs will coincide. Four of these spaces in the

arc dub , which represents the front of the arch, reach from t to d , viz. to the abutment on the side, where it forms an obtuse angle with that front, whilst the same number of similar spaces in the like direction extend only from t to 4 , in the arc xvy , representing the internal end or extreme extent of the voissairs seen on the face of the arch. The same circumstances are reversed on the side where the front forms an acute angle with the abutment, as shewn by the similar references on the other side of tt : consequently the joint 4 , in front of the arch, will fall into the impost at y on the rear line. The radiating lines rising above each arc, drawn from their respective centres b and g , shew the twist or different sommering lines at each extremity of the same joint: the difference of these divergencies would be more clearly seen by exhibiting similar lines upon the arc rvs , which represents that of xvy , upon the same level as the front arc dub , preserving an equal lateral distance between them, which as it may be easily conceived is left undone, because they would interfere with the lines requisite for the further explanation of the subject. The points, r and s , upon the last described arc, correspond with x and y upon that for which it is substituted, every remaining letter or figure of reference being the same in both.

The vertical spaces on the acute side of the arch intercepted between $4s$, 33 , &c. until they become horizontal at t , shew the proportionate depression of the soffit of the joints they represent; and on the other side, d to 4 , on the lower dotted arc; 33 , &c. shew the rise on each voissair abutting on these points. The horizontal base between the extremities of each joint is shewn by the lines dn , zm , kk , &c. which extend between the chords db and xy , from the points found by the intersection of the ordinates from the correspondent numbers of their respective curves. The horizontal base, kk , is the only one that is rectangular to the chord of the arc; all the other bases diverging towards that abutment which forms an obtuse angle with the arch, and increasing towards the haunches. At the first view of the diagram they appear to diverge both ways, but on investigation it will be seen that the letter n , on the side of the acute angle, has reference to the front arc, and on the other side refers to that representing the inner end of each joint. From these data we shall proceed to shew the longitudinal section or side elevation of a voissair at tt , and other parts of the arch: k , k , fig. 5, correspondent with k , k , fig. 4, but on a larger scale, expresses the base of the voissair, and k , r , its height of face, or its width of bed, which latter may be assumed to be similar in the others, viz. d , i , fig. 6. and 4 , i , fig. 7. The rise of the curve in the soffit between k and k , must obviously be equal to the difference between the ordinates tk and ur , fig. 4, because the crown of the arch shewn by the line vu , must be intersected at half-way between t , t , the extremes of the voissair; one end of the stone being on that side of the crown descending to the left, and the other extremity equidistant on the side descending to the right. The breast-wall is shewn rising rectangular from this voissair. Fig. 6. upon the principles already explained, shews on the side where the front line of the arch makes an obtuse angle with its abutment, the voissair rising from the springing point at d to 4 , on the posterior arc which corresponds with its inner extremity; and fig. 7. exhibits, on the side where the front is acute with its abutment, the bed of a voissair commencing at 4 , on the front arc dub , and descending to the abutment at s , on the arc representing the other extremity. By these diagrams it appears, that under equal widths of bed the space between the intrados and extrados increases upon the face of the arch as the haunches

of the arch are approached: therefore the rough blocks for the voissairs must be increased in their breadth of face to allow for the further divergency of their sommering lines, arising from their height of face, or difference between intrados and extrados, being increased as the secants of their angles of deviation from a rectangle with a line between each extremity of their soffit: viz. as dz is to d , i , fig. 6, or $4r$ to 4 , i in fig. 7. And if the twist of the sommering lines be attended to, the long voissairs must have a still greater width of block between their beds than the short ones: therefore, previously to the fitting each stone to its individual place, as the work advances nothing more can easily be done than giving due allowance to the first of these variations, which will be sufficient in practice where the arch, excepting its quoins, is formed of brick; because the facility of making the brick sheeting break joint with the stone voissairs of the face, will render it unnecessary to twist the beds of the latter, and with the precaution mentioned, and the necessary aid of a bevil rule with a moveable joint, and its long arm formed of short jointed links to suit the curve of the soffit, in the direction of each stone and towards the haunches on each joint of it, the operations of fitting each voissair to its place will not be difficult.

Fig. 6. sufficiently shews the danger of the breast or face-wall sliding outwards on the acute angles of the soffit; therefore, when the obliquity of the arch is carried near to that of Finlay bridge, which these diagrams represent, either the breast-wall should be curved, where it forms an obtuse angle with the abutment, or the voissair should have offsets, which may be of the breadth of a brick, if the wall be built of that material, to form a stop to its slipping forward, as shewn by the dotted lines under it in fig. 6.

We shall now point out some anomalies from the leading principle, which are necessary to be adverted to, for a due knowledge of the mode of constructing oblique bridges.

A semicircular arch obviously covers a semi-cylinder; and a lesser portion of the arc of a circle will consequently cover a similar portion of it. If it be supposed, in either instance, that the cylindric segment, lying horizontally on its plane, with its axis in the direction of its abutments, is longer than necessary for the road-way over it, in any given oblique direction; we then, to obtain an oblique arch, have only to conceive the convex face of the cylindric segment to be cut down between two parallel vertical planes, in the direction required. But this arch, from the nature of cylindric sections, will be elliptic; which is not so eligible in practice, because of its quicker rise at the haunches of the arch, the inconveniences of which have already been explained; and they obviously militate not only against the elliptic form, but also any near approach to a semicircle.

We have observed that the leading principle of these oblique arches is, that each course of voissair should run rectangular to the face of the arch. This, however, must be taken in a limited sense; because if the sheeting, or bed of the arch, were unfolded, or laid into a plane, its faces on the two extremities, bounding the passage over it, would not be straight lines parallel to each other, like the parapet walls; but would form two curved lines, each convex where the line of the arch is acute with the abutment, and concave when it approaches the other side where the intercepted angle is obtuse. This irregularity necessarily arises from the circumstance, that each front line of the sheeting, m , g , p , and n , h , q , fig. 8, in its course from the crown of the arch, in a direction oblique to g , b , (the axis of the vault transverse to the abutments,) must not, in its spiral gyration along the surface of the cylindric segment on each side of

$g b$, advance through equal ratios of the axis, in equal portions of the arc, but simply as the respective horizontal bases of these portions: therefore its deviation from a line rectangular with the axis becomes progressively less in its approach to each abutment.

The greater or less curvature of the two faces of the arch, when drawn out as a plane, must depend on the greater or less pitch of the arch, as shewn in *fig. 8*; where $r s$ and $t d$ are the abutments of the bridge, and, consequently, $r s d t$ the base of the arch. The angle of obliquity is here 51° , as in the preceding diagram: the line $g b$ passes along the crown of it; and the curved lines, $g m$ and $h n$, terminated by the line $m n$, exhibit half the arch of Finlay bridge, drawn out as a horizontal plane; $m n$ and $t d$ being parallel to, and rectangular from each other; and their distances from the crown of the arch, $g b$, in their respective lines, $g m$, $h n$, and $g t$, $h d$, being in one the length of the semi-arch, and the other that of its base. On the other side of the line $g b$, the curved lines, $g p$ and $h q$, connected by the right line $p q$, shew the form of half a semicircular arch of the same base, drawn out into a plane. In both exhibitions, it is clear that lines drawn perpendicular to different parts of the face of the arch, to serve as guide-lines to the joints of the soffit, would in one part converge to each other, and form triangles; and in the other part, where the face-line extended on a plane is concave, would diverge, so as, in both instances, to occasion great irregularity and difficulty in closing of the arch; which actually takes place in practice, unless due attention be paid to its leading principles, which have been pointed out in the explanation of *fig. 4*, so far as that diagram enabled them to be; which, although not to the extent requisite for the construction of the arch, may be made perfectly comprehensible to any practical man, by attention to the following instructions, *viz.* after the centres, which are placed parallel to the face of the arch, and diagonally to its abutment, are put up, and covered with their plank-sheeting, carefully set off their bounding-lines, $m p$ and $q n$, as in any other arch; so that every part of these face-lines shall be perpendicular to, or directly under, a horizontal line stretched from r to t , or from s to d , upon the level of the crown of the arch. Then, equidistant from each abutment, *viz.* along the crown of the arch, strike the line $g b$, which will of course be a straight line. Divide it into any given number of equal parts: if very oblique, ten or twelve may be sufficient; and in arches of small obliquity, a few divisions will do. The present diagram (*fig. 8*.) is more oblique than will probably be adopted; but the scale being minute, the line $g b$ is divided into only six parts, as the purpose of explanation will be equally well attained.

The figures 1, 2, 3, &c. in succession from b to g , shew the divisions on that line; and a, b, c , &c. exhibit correspondent spaces close to each abutment. These divisions being made, set out, on the sheeting, so many parallel lines to the outer faces, $m g p$, and $n h q$, *viz.* $a 1 a$, $b 2 b$, &c.: $k 1$ represents a line of joint near the crown of the arch, and rectangular to its face; which commencing at the distance of $b k$, will intersect $h g$, the line of the crown, at the distance of $b 1$, from the face of the arch; and will represent half the line, 11 , in diagram, *fig. 4*.

By the theory laid down for these arches, the joints on their soffit are to run parallel to each other; or rather they are to intersect equal portions of parallel equidistant arcs, standing in a line oblique to their common axis. This end may obviously be obtained, by setting off on each face of the arch, and on each of the parallel equidistant lines, $a 1 a$, $b 2 b$, &c. spaces similar to $b k$, in succession after each

other from the points $b 1, 2, 3, 4, 5$, and g , towards each abutment; and then to mark upon the sheeting strong lines, to direct the course of the joints, such as shewn by $k 1, 1 u, u v$, &c. which will form a polygonic curve, more or less approaching to a regular curve, according to the obliquity of the arch, and its approximation to a semicircle, and the number of divisions between b and g . The horizontal bases of the soffit joints near the abutments, on each side of the arch, are, as shewn in *fig. 4*, inclined from the line of the face towards that abutment which forms with it an *obtuse* internal angle: notwithstanding which, these joints, when drawn on the plane of the sheeting, deviate from the rectangular, with its face line towards the abutment which forms an *acute* internal angle with the line of the arch, and from the abutment on the opposite side, as shewn by those lines in *fig. 8*.

These excentricities, although they render it difficult to form all the voissiors prior to the commencement of the arch, are easily got over by forming them in succession, as described.

As the lines, $a 1 a$, $b 2 b$, &c. over the curve of the arch will be rather troublesome to form correctly, the best mode in practice will be to mark off on each face, and each side of the arch, a continuation of the spaces, $q i$ and $h k$, towards each abutment. Then as the progressive correspondent points from g and b , *viz.* $i f$, $o l$, &c. will have right lines between them, straight chalk-lines can easily be struck; and when the spaces, $b 1, b 2$, &c. are set off upon each of them, the intersecting points similar to u, v, x , &c. will be found the same as upon the lines $a 1 a$, $b 2 b$, which, therefore, have no occasion to be formed.

Had the number of divisions on the line $h g$ been greater, the curvature of the joint lines would have appeared more material on that side of the diagram, exhibiting a semicircular arch expanded; but on the other side, where the arch is of the flat pitch described, but with great obliquity, the deviation from right lines is so much less so, that in brickwork the joint-lines may easily be followed. In similar arcs of moderate obliquity, the divergency is of course less; but yet it will, unless the arch approach within about 20° of a rectangle with its abutments, be sufficient to occasion considerable irregularity, if the joint-lines be continued across, rectangular from either face.

We had frequent opportunities of seeing, for several years after it was built, the bridge from which most of the diagrams have been drawn, and never observed any crack in it; but yet from the uncertainty of obtaining careful and intelligent overseers, and good materials, and likewise because of the greater expence, and not having investigated the subject in all its bearings, so as to lay down sufficiently plain instructions, we did not then, in several bridges over the Grand Canal of Ireland, which we directed to be built obliquely, and in other bridges, subsequently, over wide drains in the East Riding of Yorkshire, venture to exceed 40° of obliquity, and rarely 30° , although the angle of intersection of the road and water was generally more considerable. It is clearly evident that this extent of angle would often be highly useful, as it would rarely leave much to be made up by the deviation of the road from its usual direction. The wing-walls of Finlay bridge were curved one more than the other on the same side, to give a passage along each bank of the canal; but where not over a canal, if the line of direction of the road coincide with that of the bridge, the wing-walls may terminate more nearly square with the road, or completely so, as in *fig. 9*, which shews one of these bridges under an obliquity of about 40° , with the arch unclosed, so as to shew the wood sheeting supporting

it, and the mode of closing it without unequal pressure on each side of the centres.

From what has already been explained, it necessarily follows that each impost of the arch, in place of being simply sommered to the radiating line of the incumbent curve, must also, as appears in *fig. 3*, be serrated (as shewn between *c* and *c*; *fig. 8*.) to suit the adjoining bed of the stones, or bricks, forming the arch.

The casual utility of these arches is obvious, and the theoretic and practical mode of forming them has been explained to such extent, as to make the process easy to any intelligent mason. Since the period we have mentioned, the plan has in a few instances been followed; and the same idea may have occurred to others, although we have never heard of it.

The principal use of these bridges will be where lines of projected canals intersect high roads with obliquity; in

which case, the road, if curved for a sufficient extent to fall in with a rectangular passage over the canal in so gentle a manner as it ought, would require a considerable length of double curve, *viz.* alternately outwards and inwards on one side, or both, accordingly as the bridge might be placed, an instance of the latter of which is shewn in sketch N^o 10. Under this predicament, where the land is valuable, or houses interfere to interrupt the change of road, it may often be found advantageous, because more economical to incur the increase of expence attendant on the construction of an oblique bridge; which, under moderate angles of departure from the right line across, is not very material; and where it becomes so, will sometimes be greatly inferior to the advantages acquired by it. We have been indebted for the preceding article to — Chapman, esq. a well-known and ingenious engineer, to whom we have already referred under the article 'CANAL.

Ochre

OCHRE, in the *Arts*, a yellow powder of an earthy appearance. It in general consists of some earth, as lime or clay, combined with a sub-salt or oxyd of iron.

The oxyd of iron in this substance is mostly combined with either the sulphuric or carbonic acids, and in general is derived from the decomposition of super-sulphuret of iron. By exposure to the air and moisture, the latter substance is converted into sulphuret of iron. This salt, by exposure to the oxygen of the atmosphere, soon resolves itself into two salts, namely, the super-oxyfulphat of iron and the sub-oxyfulphat. The latter, being insoluble, is precipitated, forming a yellow deposit, frequently seen in such chalybeate springs as result from the decomposition of pyrites. This yellow precipitate penetrates the earth and tinges it with the same colour, but more dilute. The mixture constitutes a species of ochre. When the soil, with which the subsalt combines, consists of certain proportions of lime and alumine, free from stones or other heterogeneous matter, the ochre is more valuable.

Those chalybeate waters which contain the super-carbonat of iron, and which are frequently found, are capable of forming ochre, but of a different quality from the last. The carbonat held in the water is super-carbonat with the black oxyd of iron. By exposure to the air an atom of carbonic acid escapes, the oxyd takes another atom of oxygen from the atmosphere, and is precipitated with the other atom of carbonic acid in the form of oxycarbonat, which is in the form of an insoluble powder of a yellow colour. This ochre is of a deeper yellow than that derived from the sub-oxyfulphat. Its colour may be converted into a beautiful brown by applying a heat to it, sufficient to expel its carbonic acid, leaving behind the second oxyd of iron. The heat of boiling water is sufficient for this purpose. This ochre, so changed, has most of the properties of umber. The sub-

fulphat does not so readily assume the brown colour, on account of the greater heat required to expel its acid.

Artificial ochres may be prepared of equal, and perhaps of superior quality to those in nature. The fulphat of iron in the manufacture of this article, previous to its crystallization, is partly in the state of oxyfulphat, and becomes wholly so by long exposure to the air. As it remains in this situation it will gradually resolve itself into the super oxyfulphat and the sub-oxyfulphat. The latter falls to the bottom of the vessel in the form of a yellow powder, which, when washed and dried, constitutes a beautiful colour.

When carbonat of potash is added to the super-oxyfulphat, the carbonat of iron will be formed, which will precipitate in the state of a yellow powder. This powder, when washed, and the water evaporated, constitutes an ochre which is a little deeper in colour than the last. The heat of boiling water drives off the carbonic acid, leaving the oxyd of an agreeable brown colour.

OCHRE, in *Agriculture*, a sort of oxyd or calx of iron, which is frequently met with in some sorts of soil. The author of *Phytologia* states, that red ochre may in some cases be favourable to vegetation, though it has generally been supposed prejudicial to it.

It is, however, stated by Mr. Nicol, that the most untoward of all soils, for the produce of timber in high perfection, is an iron till of little depth, lying on a retentive subsoil, which upholds a poisonous ochry water, and which stagnates on the surface, or remains latent in the body of the soil, which is the pasture of the roots, contracting the mouths of the fibres, contaminating the juices, and finally operating to the destruction of the tree, by poisoning it, and hastening its dissolution.

It is well known that ochres also form the basis of various kinds of pigments, paints, and other similar matters.

Oil

OIL, in *Chemistry* and the *Arts*. Oils are divided into two classes: A. *Volatile*, and B. *Fixed oils*. The latter into two orders; *a*, fat, and *b*, drying oils.

A. *Volatile or Essential Oils*.—These are so called because

they are evaporable at a moderate heat without decomposition, and because in them the odour or fragrance, or as the old chemists called it, the *essence* of vegetables consists. Oils of this kind are obtained generally from vegetables, and some varieties from animals. They are extracted from the roots,

leaves, flowers, seeds, and fruits of vegetables, but seldom from seeds with two cotyledons, which generally afford the fixed oils; while the husk, or cover of the seed, is always more or less impregnated with volatile oil, the acrimony of which defends in some degree the rudiments of the young plant from the depredations of insects. The volatile oils, which are procured from the fruits of the lemon, the orange, and the bergamotte orange, are those which alone are capable of being obtained by expression. For this purpose a small wheel, with its circumference set with stout nails, is put in motion, and a lemon or orange is applied to it till the whole of the yellow outer rind is rasped away. The raspings fall to the bottom of the case in which the wheel turns, and they are then squeezed between two plates of glass. By this gentle pressure the essential oil flows from the ruptured cells into any adjoining vessel, and is there suffered to rest till the water and other impurities have subsided. In a way similar to this is obtained in India the precious perfume called the oil or "otter" of roses. For this purpose a clean cask or glazed earthen jar is filled with rose-leaves separated from its calyces, which are covered with spring-water. The vessel is then set in the sun for two or three days, and brought under cover in the night. At the end of the third or fourth day small particles of yellow oil will float on the surface of the water, which in a week will have accumulated into a thin scum: this scum is taken up by a little cotton tied to the end of a stick, and squeezed into a small phial.

Essential oils are generally obtained by distillation. The fresh herbaceous plant, or the dried plant, previously macerated for a few hours in water, or the bark or wood rasped or cut into shavings, and macerated for several days, are closely rammed down in a tinued copper still or alembic; and when covered with water, the head of the still is luted on and the refrigerator filled with cold water, and then the fire is lighted and so regulated as to keep the contents of the still constantly simmering, without boiling. The steam condensed in the worm will form a small stream of water, which is to be collected in proper vessels, till it comes off nearly insipid and inodorous; and then the distillation is stopped. The first part of the produce, as it is turbid from supersaturation with essential oil, is kept for some hours in a cold place, during which time the excess of oil will separate from the water, and either float on the surface or sink to the bottom, according to its specific gravity. The oil is completely separated from the distilled water by an instrument

called the Italian recipient; and the whole of the water produced by the first distillation is employed in the next, instead of plain water; so that thus the produce of oil in the second distillation will exceed that of the first, by the whole quantity held in permanent solution by the water of the former process. By this process, the amount of oil yielded by equal quantities of the same substance will form a constantly increasing series, till the whole of the water drawn off by each distillation is completely saturated with oil. It is not till the seventh, or even sometimes the tenth distillation, that the produce of oil attains its maximum. Essential oil may be procured not only from odorous vegetables themselves, but from such of the immediate products of vegetation as possess any odour: such are the balsams and many of the resins and gum resins. The peculiar odour of vegetables, when not in a state of decomposition, depending on the volatile oil they contain, it is plain that the odours of the oil themselves are equally various. Their taste is exceedingly hot and pungent, and in some, particularly the oil of peppermint, followed by a remarkable sensation of coldness, though the thermometrical temperature undergoes no change. The acrimony of some of the oils, as the oil of cloves, is so great as actually to destroy the outer skin of the tongue and of other sensible parts. The colours of essential oils are various, some being blue, others green; but the usual colour is light yellow, verging more or less by long keeping to reddish-brown. Other striking characters of volatile oils are that they are liquid, more or less at different temperatures, sometimes thick and glutinous like the expressed oils, and sometimes solid and in crystals. In the latter state they approach the nature of resins. They are highly combustible, producing much smoke, condensing into soot. They are also of an agreeable strong smell, and of a pungent acrid taste. They are volatile at a heat less than 212° . And they give a greasy stain to paper, but evaporate without leaving any mark. Volatile oil, however, may be detained in a higher heat by mechanical mixture with dry clay or sand; and then it undergoes a partial decomposition, carburetted hydrogen being given out, and a little charcoal remaining in the receiver; the undecomposed residue, if subjected three or four times successively to similar treatment, will be entirely destroyed.

The following table exhibits the most prominent properties of some of the volatile oils.

TABLE of Volatile Oils.

Names.	Colour.	Specific Gravity.	Consistency at 60° . Freezes at 14° .	Odour.
Turpentine - -	None.	.792	Fluid as water.	Strong.
Juniper - -	Green.	.611	Very fluid.	Strong smell.
Rosemary - -	None.	.934	Thin liquid.	Like the plant.
Mint - -	None.	.975	Very fluid.	Agreeable.
Cloves - -	None.	1.034	Oily and very fluid.	Very fragrant.
Lemon - -	Yellow.		Thin liquid.	Very agreeable.
Orange - -	Yellow.	.888	Ditto.	Nearly similar.
Cinnamon - -	Yellow.	1.035	Oily and less liquid.	Pleasant.
Sassafras - -	None.	1.094	Oily.	Like the root.
Fennel - -		.997	Becomes solid at 50° .	
Tanfy - -		.946		Very strong.
Dill - -		.994		
Carraway - -	None.	.94		Very strong and pungent.
Penny Royal - -		.978		Agreeable, like the plant.
Cummin - -		.975		

Names.	Colour.	Specific Gravity.	Consistency at 60°. Freezes at 14°.	Odour.
Nutmegs - -	None.	.948	Like butter.	Very pleasant.
Aniseed - -	None.		Becomes solid at 50°.	Very strong.
Thyme - -	Brown.		Crytallizes.	Like camphor.
Spike - -	Yellow.	.936		Very strong.
Lavender - -	None.		Thin liquid.	Very agreeable.
Origanum - -		.94		Very strong and acrid.
Wormwood - -	Green.			
Camomile - -	Blue.			
Hops - -	Green.		Like butter.	Like the flower.
Parsley - -	Green.			
Bergamotte - -	Yellow.		Not oily. Is solid at 23°.	Very pleasant.
Cardamom - -	None.		Oily.	
Mace - -			Oily.	Agreeable.
Roses - -	None.			
Peppermint - -	Green.		Thin liquid.	Very agreeable.
Savine - -	None.			Disagreeable.
Pepper - -	None.		Like butter.	Very acrid.

When the volatile oils are recently distilled they evaporate without leaving any residuum. They are distilled with greater facility when water or alcohol is present. After they have been exposed to the air for some time they do not entirely evaporate, but a slight residuum is left of the nature of resin. When deprived of heat to a certain extent they become solid, having an unctuous appearance. Some of them assume the crystalline form.

It has been asserted by Tingry, that light has the property of increasing the absolute weight of the volatile oils when exposed in a close glass vessel, the air at the same time being excluded. This fact, however, ought to be doubted, till confirmed by stronger evidence. This he attributes to the fixation of light, a thing at present unknown to chemists. The essential oils, especially the more volatile of them, de-oxygenate atmospheric air very completely, as was first ascertained by Dr. Priestley, and this circumstance partly accounts for the uneasy sensations experienced by most persons when in a close newly painted room.

The action of oxygen upon these bodies is very conspicuous. They become viscid, and assume a yellow colour. The colour becomes deeper, more especially if it is exposed to the sun, and the oil ultimately assumes the form of resin. In thick oils another change takes place; a weakly acedulous water is produced, and prismatic crystals are deposited; the residue of the oil becoming, in the mean time, concrete. These crystals, which have been occasionally mistaken for camphor, are slightly soluble in hot water, and more so in alcohol; to which they communicate the property of reddening vegetable blues; when gently heated, they swell and crystallize in needles by cooling; when heated by the blowpipe they evaporate, but do not inflame; from these properties they have been considered as an acid very analogous to the benzoic. Some essential oils afford real camphor by evaporation, as Proust has shewn. (See CAMPHOR.) If the mass so changed into resin be subjected to distillation, an oil similar to the original comes over, leaving behind a resin of greater hardness, and more infusible than the original mass. Almost all the substances denominated resin are capable of affording a portion of an essential oil by the action of heat, the resin becoming harder and less fusible. It is on these facts that the art of jarring depends. If the surface of any body be covered with common tar, and then exposed to the heat of a stove for a certain time, the oily part evaporates, leaving a hard coating, which does not soften at a heat

short of that which would decompose it, and at the same time so hard as not to be penetrable by the nail. Common pitch and resin are of different degrees of softness, according to the extent to which the distillation has been carried. The change produced in the volatile oils, by exposure to the air, has been supposed to arise from the absorption of oxygen, but in all probability this is not the fact. That oxygen disappears is undeniable, but that it is retained in the body is doubtful. We are informed by Fourcroy, that drops of water are formed when oxygen is exposed over oil of turpentine. Hence it is highly probable, that the oxygen combines with the hydrogen of the oil, forming water, which leaves a compound having less hydrogen, and in consequence more fixed and hard.

The volatile oils, from the great quantity of hydrogen they contain, take fire with great facility, and burn with a copious white flame, producing much foot. If the products of combustion be collected, they will be found to consist of water and carbonic acid, derived from the carbon and hydrogen of the oil, with the oxygen of the atmosphere.

It is by this means that we are to expect an analysis of these substances, an object which has not yet been accomplished, but which is very desirable.

The volatile oils do not undergo any change with hydrogen or carbon. They combine to a certain extent with sulphur, by which they acquire a brownish colour, and disagreeable smell. This sulphurized oil gives out on distillation sulphuretted hydrogen; it is often called "balsam of sulphur."

It is said that these compounds are decomposed by heat with a violent effervescence, which is supposed to arise from the sulphur combining with the hydrogen, forming sulphuretted hydrogen.

Camphor, which may be deemed a concrete volatile oil, combines with phosphorus by trituration. This compound may afterwards be dissolved in most of the volatile oils. The solution is luminous when exposed to the air, so as to tell the hour of the night.

Water has little action upon the volatile oils. The water, however, dissolves as much as gives it a strong taste of the oil. When the oil is first dropped upon sugar, and this put into water, a greater quantity is retained. Advantage is frequently taken of this fact in pharmacy.

They are mostly soluble in alcohol and ether, though in limited proportions.

The alkalies have much less action upon the volatile oils than upon the fixed oils. They are more susceptible of combining with these bodies, in proportion as they approach the state of resin. Common turpentine combines with potash, while oil of turpentine is but with difficulty made to unite with it. This has been called *Starkey's soap*.

We are in possession of some facts relative to the action of acids upon the oils.

The sulphuric acid dissolves them, and mutual decomposition takes place. The colour becomes dark, and charcoal is at length deposited. When water is poured upon the solution, a resinous mass becomes separated. Hence it appears, that the oxygen of the sulphuric acid produces a similar change with the oxygen of the atmosphere.

The nitric acid, when poured upon most of the essential oils, causes them to inflame with great violence, leaving behind a spongy coal of a brown colour. The acid should be very strong for this experiment.

Muriatic acid slightly dissolves these substances, but we have no facts as to their mutual change.

It may easily be conceived, that many of the metallic oxyds will produce the same changes upon the volatile oils which are produced by the acids, and the oxygen of the atmosphere. The facility with which lead, mercury, and manganese give up their oxygen, offers a ready method for an accurate analysis of these bodies.

The volatile oils are used in medicine, and are considered stimulants. They are also used as perfumes; and in the composition of varnishes and oil paints.

Fixed, Vegetable, or Unctuous Oils.—The fixed oils have the following characters:

1. They are greasy to the touch.
2. They are mostly liquid, or rather in the state of a moderately thick, but not viscid, fluid, at the common temperature of the atmosphere, but become solid at certain degrees below.
3. They do not boil at less than 600°.
4. They take fire at a certain temperature, and burn with different degrees of brilliancy.
5. They are not acrid like the volatile oils, but frequently almost insipid, or possessing a mild sub-nauseous taste, and a peculiar flavour, according to the vegetables from which they are produced. Their colour, when recent, has more or less of a greenish tinge, which by keeping becomes yellow, and in some instances orange-coloured, verging on red. Their specific gravity is usually between that of alcohol and water, as they sink in the former, and float on the surface of the latter. Of these fluids, there is no circumstance in which they differ so much as in the temperature at which they congeal: some continue solid at the highest atmospheric temperature, as palm oil, and the rest of the vegetable "butters," as they are called from this circumstance; others require being cooled down to the freezing point of water; and others, again, are capable of enduring a much greater degree of cold without becoming solid.
6. They are insoluble in water and alcohol.
7. They leave a stain on paper, which cannot be removed by evaporation.

Fixed oils are so called, because they are incapable of being volatilized by heat without decomposition. When any of them, *e. g.* olive oil, is heated in a close distillatory apparatus, as soon as the fluid has arrived at its boiling point, a white vapour is disengaged, consisting of oil, carburetted hydrogen, and carbonic acid. The first of these is for the most part condensed in the receiver; while the other two, retaining in solution a portion of oil, escape in the form of permanent gas: and when every thing volatile has been

driven off, nothing remains in the retort but a little charcoal. The oil which is found in the receiver is lighter, more limpid and volatile, than that from which it was procured; and these qualities are observed to increase by each successive distillation; carbon and carburetted hydrogen being disengaged as at first. By continuing this process with the product of each distillation, the oil at length entirely disappears, being partly decomposed, and partly carried off in solution by the carburetted hydrogen gas.

They are principally procured from the cotyledons of seeds, and sometimes, though rarely, from the pulp or flesh of fruits. The substance containing the oil is beaten to a pulp, and then heated to a certain temperature. It is then subjected to the action of a strong press, to force out the oil. Much of the mucilage is carried off with the oil. This is more particularly the case when the pulp is heated. If it be pressed cold, the oil is much freer from colour, and in a state of greater purity; but the quantity obtained is less. The oil obtained in this way is said to be *cool drawn*. If the heat be too great, the oil will be more coloured. The kernels of the common nut, the walnut, and the hickory nut, yield an abundance of oil: it is also expressed from the seeds of the lint, the rape, the poppy, and the sun-flower; and in great abundance from the exterior substance of the olive. All the fixed oils, except the latter, are obtained from the cotyledons of seeds; and it is remarkable that no seed with one cotyledon affords a fixed oil. Oil may be extracted not only by pressure, which is the most common method, but by immersion in hot water. In this latter case, the oil separates from the other ingredients with which it is naturally mixed, and rises by the force of gravity to the surface of the water, from which it is skimmed off. Recently drawn oil is more or less impure, on account of its containing a variable proportion of mucilage, fecula, and perhaps other substances: of these a part is always deposited by rest, especially if the contact of the air is not wholly excluded; but another portion remains in permanent solution; and to this that partial spontaneous decomposition in oils, called "rancidity," is principally owing. They are also obtained from animals, such as whale oil and neat's-foot oil.

All animals, except those included in the class of insects, contain oil; the quantity of which, as well as its situation in the body, is subject to considerable variety. (See *CELLULAR Membrane*, *ADIPS*, and *SEBACIC Acid*. See also *Anatomy of BIRDS, FISH, and MAMMALIA*.) While the fat remains in the living body, it is always in a fluid or semi-fluid state; but its consistence changes, when it is extracted and exposed to the common temperature. The oil or fat, investing the kidneys of quadrupeds, is called suet or tallow, and is the hardest and most solid of any; the next in hardness is the fat of the bones, and that in which the muscles are imbedded is the next in degree: the fat of the hog, called "lard," is the least solid. The fat of birds is seldom so solid as hog's lard, and in many species is actually fluid. The fat or oil of fish is almost always fluid at the common temperature. There is also fat in the yolk of eggs, which may be extracted by simple pressure, after the yolk has been coagulated by heat.

Animal oil is obtained in its purest state by shredding fresh suet, and liquefying it in boiling water, and then passing it through a piece of thin gauze, in order to separate the cellular membrane. Thus purified, its colour is yellowish-white: it is moderately hard, of a mild taste, and almost destitute of odour or flavour; it is combustible, like the fixed vegetable oils, and agrees with these in the changes produced upon it by the alkalies and other chemical re-agents.

All the animal oils belong to the class of unctuous or fat oils, none of them being either drying in themselves, or capable of becoming so by means of litharge and other substances. Fat, exposed to dry distillation, when it acquires the temperature of about 400°, emits a white acrid and disagreeable vapour: as the heat increases, some of the oil comes over into the receiver, and that which remains in the retort acquires a blackish tinge; empyreumatic, acetous, and sebatic acids manifest themselves, together with carburetted hydrogen and carbonic acid of a very offensive odour. Hence it is inferred that there is a real difference between animal and vegetable oils, though it has not been pointed out by chemical analysis. The coarser kinds of animal oil, extracted by putrefaction and a strong heat, possess a much more disagreeable odour than any of the vegetable oils; and, when rancid, disengage ammonia by the action of the fixed caustic alkalis, in which they also differ from the latter. The fish oils, always rancid, are for the most part thick and glutinous, which renders them in some degree unfit for burning, and some other uses to which they are applied. Many attempts have been made to meliorate them; and it appears by the experiments of Mr. Dossie, that they may be considerably improved by means of fixed alkali and chalk, by which the albumen and gluten are thrown down, and the supernatant oil, after due rest, may be poured off in a fluid state, and very sensibly amended in consistence, odour, and fitness for burning. Animal oils are substances of very great economical importance. They are used as food, and in medicine as the basis of various unguents: they are largely employed in the manufacture of soap, and also for burning either in lamps or in the form of candles. Aikin's Dict.

Whale oil is much contaminated by different animal matters, to which it owes its disagreeable odour. It has, however, been so purified as to possess less smell and taste than the best olive oil.

All the fixed oils are of less specific gravity than water; and since they do not combine, the former must float upon the surface of the latter.

The fixed oils cannot be distilled without decomposition. They boil at 600°: a vapour comes over, which condenses into an oil, which is different from the original. An inflammable gas is disengaged, and some coal deposited. This is some proof that decomposition takes place. From these facts we may fairly conclude, that the oil of lamps and candles, when in the act of burning, undergoes decomposition. The inflammable gas and the vapour constitute the volatile part which makes the flame, while some carbon is separated, which lodges in the wick.

Fixed oils are divided into two orders: (a), *fat oils*, and, (b), *drying oils*.

(a). *Fat Oils*.—These are such as, when exposed to the air for a certain time, first become viscid, and ultimately concrete, having the appearance of tallow, and in every respect similar to fat. This oil will be more or less hard, according to the time exposed: it at the same time acquires a disagreeable odour, to which we give the name of rancidity. Of these kinds we may mention olive oil, almond oil, and that extracted from rape seed, called rape oil. This change is more rapidly brought about by dilute nitric acid, or any substance which affords oxygen. It has been supposed that the combination of the oxygen with the oil gives to it the concrete form. It is, however, to be regretted that we have not as yet learned from any experiments, whether the absolute weight of the oil be increased or diminished by the agency of the oxygen. It seems most plausible to suppose, that the oxygen combines with a portion of hydrogen of the

oil, forming water, leaving the remainder more concrete and less fusible. Olive oil, by treating it with nitric acid, may be rendered equally infusible with spermaceti.

The fat oils combine with the alkalis, earths, and most metallic oxyds, forming soaps. See SOAP.

They are not miscible with water, except through the medium of sugar, starch, or gum. With the two latter they form compounds, called *emulsions*.

They do not combine with many of the combustible bodies. They unite with sulphur, forming a dark brown compound of a disagreeable smell. On cooling, some of the sulphur is deposited in crystals. Phosphorus combines with several of the fat oils. Olive oil, when rubbed with phosphorus in a mortar, dissolves a portion of it. The solution, when exposed to the air, by opening the bottle containing it, becomes very luminous. Any substance smeared with it shines for some time, but no perceptible heat is produced.

When concentrated sulphuric acid is poured upon the fixed oils, decomposition speedily ensues. The products are water, carbon deposited, giving a black colour. The sulphur is also deposited, and some acetic acid formed. When concentrated nitric acid is poured upon oils, the action is considerable; the oil takes fire, and burns, leaving a spongy coal behind. If the acid be dilute, as has been observed, it converts the fat oils into fat like tallow.

The fixed oils combine with some of the metals. A leaden vessel soon becomes corroded by oil contained in it; the oil at the same time becoming thicker. They have scarcely any action upon tin; hence the use of the latter metal in preference to the former for oil vessels. Oil has also a decided action upon iron, as we see in the axle-trees of carriages, and in all instances in which oil is used with iron to lessen friction.

b. *Drying Oils*.—These oils possess properties mostly common to both, but differing in some particulars. They, like the fat oils, become concrete by the action of oxygen; but instead of assuming an opaque fatty appearance, they retain their transparency, and acquire the flexible property of horn.

The varieties possessing this property are the oils of nut, poppy, and lint.

These oils are less fitted for combustion than the fat oils, but are of great use for paints and varnishes, and making printers' ink. When used for the latter purpose the nut oil is preferred, on account of its not turning yellow. It is first set on fire, and allowed to burn for a short time; it is then covered by a lid to extinguish it, and allowed to boil for some time. By this treatment it loses its greasy quality, becomes thick and roapy, and is more miscible with water, a property of great importance in the above application. Drying oils become more susceptible of the concreting quality by being boiled with litharge, or almost any substance containing oxygen. Doubtless in this process the oxygen of the lead combines with the hydrogen of the oil, while the lead combines with the oil, to which it gives a dark colour, and makes it thicker. Acetat of lead, and other metallic salts, produce the same change.

When oil is mixed with the black oxyd of manganese, it some time after takes fire. This arises from a more rapid combination of the oxygen of the oxyd with the hydrogen of the oil.

The composition of the fixed oils has been given by Lavoisier, but it is not to be relied upon. He makes it consist of 79 carbon, and 21 hydrogen.

Another species of oils is found in some vegetables, which have an acrid taste, and dissolve in alcohol, like the

volatile oils, but are not so volatile as to admit of distillation. The vegetable containing the oil is infused in alcohol, which dissolves the oil. The alcohol is afterwards distilled from the oil.

These oils are said to be poisonous, which appears to be their most distinguishing character. An oil of this kind is obtained from the root of the helleborus hyemalis, and another is found in tobacco.

OILS, Empyreumatic.—These approach the nature of volatile oils, and are formed during the distillation of vegetable and animal substances. They have properties nearly allied to tar, and afford, by a second and careful distillation, a liquid volatile oil, not much unlike the oil of common tar, which has many properties in common with oil of turpentine. A similar substance is obtained from pit-coal by distillation, which oil belongs also to this class.

The colour of empyreumatic vegetable oil is yellowish-red, passing into blackish-red; it has a strong odour, and an acrid empyreumatic taste; it is more volatile than the fixed oils, but less so than the proper essential ones; by re-distillation with a little water it almost wholly loses its colour, and becomes more volatile than before, though still possessed of much of its empyreumatic flavour. See Aikin's Dict.

The use of oil in stopping the violent ebullition of various substances, may be very great in many occasions of life. It is well known that if a mixture of sugar, honey, or the like, be boiling on the fire, and in danger of rising over the sides of the vessel, the pouring in a little oil immediately makes it subside. In many cases, the marking a circle round the inside of a vessel, in which a liquor of this kind is to be boiled, with a piece of hard soap, shall, like a magic ring, confine the ebullition to that height, and not suffer it to stir any farther. This is wholly owing to the oil, or fat, contained in the soap; but there is, besides these, another very important use of oil, on a like occasion, which is the pouring a little of it on any metallic solution, while making; this restrains the ascent of the noxious vapours; preserves the operator from danger; and, at the same time, by keeping down the evaporating matter, gives redoubled strength to the menstruum.

Pliny has mentioned an extraordinary effect of oil, in filling the surface of water when it is agitated with waves, and the use made of it by the divers, for this purpose. "Omne," says he, "*oleo tranquillari*," &c. lib. ii. cap. 103. and Plutarch, in *Quæst. Natur.* asks, "*Cur mare oleo confusum perlucidum sit et tranquillum?*" Pliny's account seems to have been either discredited or disregarded by our writers on experimental philosophy, till it was confirmed by several curious experiments of Dr. Franklin, which were published in the year 1744.

The property of oil above-mentioned has, however, been well known to modern divers and dredgers for oysters, at Gibraltar, and elsewhere. The divers in the Mediterranean, in particular, descend, as in Pliny's time, with a little oil in their mouths, which they now and then let out; and which, on rising to the surface of the sea, immediately renders it smooth, so as to permit the light to pass through the water, undisturbed by various and irregular refractions.

The Bermudians, it is said, are enabled to see and strike fish, which would be concealed from their view, through the roughness of the sea, by pouring a little oil upon it. And the Lisbon fishermen effect a safe passage over the bar of the Tagus, by emptying a bottle or two of oil into the sea, when the surf is so great as to endanger its filling their boats. Our sailors have also observed, that the water is al-

ways much smoother in the wake of a ship that hath been newly tallowed than it is in one that is foul.

Dr. Franklin was led, by an accidental observation made at sea in 1757, to attend particularly to Pliny's account; and the various informations which he afterwards received relating to it, induced him to try some experiments on the subject. Standing on the windward side of a large pond, the surface of which was rendered very rough with the wind, he poured a tea-spoonful of oil on the water. This small quantity produced an instant calm over a space of several yards square, which spread amazingly, and extended itself gradually, till it reached the lee-side, making all that quarter of the pond, perhaps half an acre, as smooth as a looking-glass. On repeating this experiment, which constantly succeeded, one circumstance struck him with particular surprise; this was the sudden, wide, and forcible spreading of a drop of oil on the face of the water, which, he adds, "I do not know that any body has considered."

When a drop of oil is put on a looking-glass, or polished marble, it spreads very little: but on water it instantly expands into a circle extending several feet in diameter, becoming so thin as to produce the prismatic colours for a considerable space, and beyond them so much thinner as to be invisible, except in its effects of smoothing the waves at a much greater distance. It seems, says Dr. Franklin, as if a mutual repulsion between its particles took place as soon as it touched the water, and a repulsion so strong as to act on other bodies swimming on the surface, as straws, leaves, &c. forcing them to recede every way from the drop, as from a centre, leaving a large clear space. The quantity of this force, and the distance to which it will operate, the author says, he has not yet ascertained; but he thinks it a curious enquiry, and wishes to understand whence it arises. In endeavouring to account for the singular effects of oil, Dr. Franklin observes, that there seems to be no natural repulsion between water and air, so as to keep them from coming into contact with each other. Therefore air, in motion, which is wind, in passing over the smooth surface of water, may rub, as it were, on that surface, and raise it into wrinkles, which, if the wind continues, are the elements of future waves. The smallest wave does not immediately subside, but in subsiding raises nearly as much of the water next to it. A small power, continually operating, will produce a great action: so that the first raised waves, being continually acted upon by the wind, are, though the wind does not increase in strength, continually increased in magnitude, rising higher and extending their bases, so as to include a vast mass of water in each wave, which, in its motion, acts with great violence. But if there be a mutual repulsion between the particles of oil, and no attraction between oil and water, oil dropt on water will not be held together by adhesion to the spot on which it falls; it will not be imbibed by the water; but be at liberty to expand itself and spread on a surface, that prevents, perhaps, by repelling the oil, all immediate contact; the expansion will continue till the mutual repulsion between the particles of oil is weakened, and reduced to nothing by their distance.

Dr. Franklin imagines, that the wind blowing over water, thus covered with a film of oil, cannot easily catch upon it, so as to raise the first wrinkles, but slides over it, and leaves it as smooth as it finds it. It moves a little the oil, indeed, which being between it and the water, serves it to slide with, and prevents friction: hence the oil dropt on the windward side of the pond proceeds gradually to leeward, as may be seen by the smoothness it carries with it quite to the opposite side: for the wind, being thus prevented from raising the first wrinkles, which he calls the elements of waves, cannot

produce waves, which are to be made by continually acting upon and enlarging those elements, and thus the whole pond is calmed.

Upon the whole, there is great room to suppose (notwithstanding the partial failure of an experiment made at Portsmouth, by Dr. Franklin, and others), that sea-faring people may derive advantages from using oil on particular occasions, in order to moderate the violence of the waves, or to lessen the surf, which sometimes renders the landing on a lee-shore dangerous, or impracticable.

To this purpose we are informed that the captain of a Dutch East India ship, being overtaken by a storm, found himself obliged, for greater safety in wearing the ship, to pour oil into the sea, to prevent the waves breaking over her, which had an excellent effect, and succeeded in preserving her. *Phil. Trans.* vol. lxiv. part. 2. p. 445, &c.

OIL, in *Agriculture*, a fatty unctuous material, obtained from animal as well as vegetable substances. These matters are distinguished into different kinds, as ethereal or essential, and fat or fixed oils: the former are acrid, volatile, odoriferous, and exist in the plants in the same states in which they are found; while the latter are fixed, destitute of odour, and mild to the taste. These last, when kept a long time, corrupt and become rancid. They do not act upon earths, but readily combine with alkaline salts, with which when caustic they form vegetable soaps.

Though these matters cannot be employed by the farmers in their simple states, as being too expensive, and having rather a noxious or poisonous effect, than a beneficial one on the growth of plants, they may frequently be used in the condition of composts with advantage, as has been the case in the application of various of the grosser sorts of materials of this nature, such as those of whale blubber, the bottoms and refuse of oil casks, &c. when blended with earthy materials, so as to be laid upon the land in an even and regular manner. And in this state of combination they have been found, by the experiments of different cultivators, to form very strong and powerful manures.

The account of Mr. C. Baldwin's trials made with the bottoms or *foots* of oil, and a rich thick South-sea whale oil, in the whole sixty gallons, is thus stated.

Having a platform or bottom of twenty loads of mould, with eight loads of dung on it, he carried on three loads of light sandy mould, and one load of brick and mortar rubbish, ground fine, and having mixed these well, and made a kind of dish of it, about five feet wide and ten feet long, with a ladle he had put over it one-half of the oil. It was in August, and the warmth of the sun soon made the thick oil soak into the compost, when it was directly thrown up in a heap, broke down again, and by five or six turnings well mixed together, and left in a heap two days, when it was spread equally over the whole dunghill; twenty loads more of good mould were then carried on, eight loads of dung, and the remaining thirty gallons of oil were mixed as before, in sandy mould, and brick and mortar rubbish, and equally spread over, and the whole was covered by trimming the four sides of the dunghill, and throwing it on the top. And thus the dunghill lay more than two months, when it was cut down by mattocks, carefully broke, well mixed, and turned over. The end of March it was carried on the field, spread and ploughed in; it lay about a fortnight, and was then ploughed again, and on the 22d of April it was drilled with the Rev. Mr. Cooke's excellent drill. The field was drilled with barley, two bushels to the acre; the crop came up in a most even and beautiful manner; every seed was up within forty-eight hours of each other; all was ripe at the

same time, and, from a couple of months after seed-time to harvest, was rated by all who saw it, and it was seen by many, as a sixty bushel crop. At harvest, three rows were cut across the field, directly thrashed and measured; one load out of thirteen was also thrashed and measured, and both stated the crop to be sixty bushels; but to waive all possibility of dispute or doubt, he is content to state the crop at seven quarters *per* acre. As to the quality of the barley, he could here cite the opinion of one of the most eminent brewers in London, who saw the crop growing, and declared he would readily give 1000*l.* to be assured that all the barley crops in the kingdom were of equal burthen and weight; five quarters of it have been lately sent to Nethrapps, in Norfolk, as feed-barley, under the denomination of 15 comb-barley; and an eminent maltster tells him it weighs 220*lbs.* *per* sack, or 55*lbs.* *per* bushel, Winchester measure. It is added, that among the many gentlemen and farmers who saw the crop on the ground, was the celebrated Mr. Bakewell; he came with three or four others, and walking down the field, observed the hedge and bank; the bank, upon being touched with a stick, run down as sand and gravel generally do, and Mr. Bakewell being asked his opinion of the value of the land, if he does not mistake, valued it at 18*d.* *per* acre, but turning to the crop, and desiring his friends to do so also, he admitted that it seemed as if growing on land of 15*s.* or 20*s.* *per* acre. He must not omit saying that the barley followed oats, upon a lay of six years old; that the land was, as is too common in such cases, much infested with the little red or wire worm, and that the oats suffered much from them; when they were ploughing for the barley the first time, he observed many turned up by the plough, when a distant ray of hope instantly darted upon his mind, that the soil in its then state, or from its strong effluvia, might prove obnoxious to them, and he is happy in saying, that the barley did not suffer from them in the least.

It is further stated, that he is trying the experiment in Hampshire, having last autumn made up a dunghill, with twenty gallons of oil, on one-third of it for a six-acre field, which is now drilled with pease.

And he concludes by observing, that it is well known that all animal substances, in a state of corruption, wonderfully promote vegetation, and are the actual food of plants. The whale-oil which he used is an animal substance, perhaps the richest part of the animal; whether he used enough, or what is the proper quantity *per* acre, experience must point out; say he used eight loads of mould, three or four loads of dung, and twelve gallons of whale-oil *per* acre. That oil applied to land, as a food for plants, in its crude state, acts as a poison he cannot deny; but his process is very different: he believes that oil, particularly animal-oil, is the pabulum of plants, that is, oil subtilized by the salts in a compost dunghill, left there a considerable time in a state of putrefaction, and until the whole is become putrescent; then he believes he has got the best and richest manure that can be carried on land. The barley evidently proved its excellence; a ridge of summer cucumbers in his garden pointed out to many its great power, the leaves being in general from ten, to ten and a half inches broad, and the vines occupied an uncommon space of ground. Five hundred cabbages and savoys, planted by the side of four thousand more, and which had only one handful of the oil manure put in each hole made by the dibble at the time of planting, were evidently near as big again as the others. See *OIL-Compost*.

OIL-Cake, the cake which remains after the oil has been expressed from flax, rape, and some other sorts of seeds. Cakes of the first sort are found to be extremely beneficial in the fattening of cattle, sheep, and other animals, in different

districts, where they are made use of upon an extensive scale.

A recent writer has stated, that the late advances in the price of this article, have probably rendered it incapable of being made use of with much profit, except in particular cases, and where manure is a principal object: with this sort of food it is the common practice to give some other sort of meat, such as hay, cut chaff, and other substances of the same nature, and some begin by giving to a beast of a hundred stones, two cakes *per* day of about six pounds each, for six or eight weeks, and then increase them to three, till the animals become fat: at first, however, as the animals seldom like it, much less may be found sufficient. In addition to the cake, from half a stone to a stone of hay is given each day, the whole consumption in cake being about 21 cwt., and in hay 26 cwt., which at the prices previous to the late advance on these articles, rendered the expense of winter-fattening an animal of the above size something more than seven guineas: lean cattle of the smaller kinds have been made perfectly fat in the course of eight or ten weeks by this substance in the trials of Mr. Moody. The cake in this application is broken down into small parts, and frequently blended with the chaff or other substances that are made use of with it. On the continent, Mr. Young says, linseed cake is sometimes exhibited in a liquid state, being diffused in hot water, and drank by the cattle, hay and other substances being given at the same time. And in the Lincolnshire report, a method is suggested of giving cake to cattle while in the pastures in a small proportion, with great success, a practice which may be applicable, where the cake-fed beasts are not fully fattened for sale in the early spring months. It is an advantage in fattening with this and other similar substances, that the animals may be completed with them at much more advanced ages than in other modes of fattening.

But wherever this expensive sort of food is employed, great care should be taken that the cakes be fresh, good, and free from mouldiness. They are the best where the expression of the oil has not been carried too far, but where this has happened they are mostly deficient in nourishment.

It has been stated by Mr. Donaldson, that in Lancashire, Yorkshire, Norfolk, and a few other districts, they sometimes use oil-cakes of the latter kind, after being reduced to powder by means of a machine contrived for the purpose, as a manure, sometimes for wheat and barley crops, but more generally for turnips. It is always sown by hand, and harrowed in with the seed. The quantity used is from three to six quarters the acre. The price is extremely different in different districts. It was then in Lancashire from six to eight shillings the quarter, in some parts of Yorkshire from sixteen to twenty. Experience has proved, that the success of this manure depends in a great measure on the following season. If rain happens to fall soon after the rape-dust is applied, the crop is generally abundant, but if no rain fall for a considerable period, the effects of this manure are little discernible either on the immediate crop, or on those which succeed it on the land in the following year.

And in an experiment stated in the eleventh volume of the Agricultural Magazine, four ridges, about twenty yards wide each, in the middle of a large field, were alternately manured with lime and rape-feed cake. The quantity of lime was, it is supposed, three chaldrons to an acre. The part oil-caked had a quarter of a ton an acre drilled by a machine, which throws the oil-cake reduced to powder, and the turnip seed, into the same drills. The soil was a strong dry red loam, with a few spots of gravel interspersed in different parts of the field. On these gravelly spots the

turnips were rather superior on the parts which were limed; but on the loam the oil-caked ridges produced, at least, double the weight of those which were limed.

Mr. Calvert, at Albury, when oil-cake was much cheaper than at present, found it the most advantageous and profitable food that he could give his cows; three cakes a day, with eight or ten pounds of hay, or four cakes and good straw, were the usual allowance; two were given to cows in calf and growing heifers: he practised this till cake advanced beyond 9*l.* a thousand. How far it may answer at much higher prices, hay and butter having both greatly advanced, careful experiments will alone ascertain, which he himself should have made, but, Swedish turnips being introduced and answering uncommonly well, he lost the inducement to go on with the other food. Cake gave very good butter, and at 6*l.* or 7*l.* a thousand was the cheapest food that could be given. Hertfordshire Agricultural Report.

Good potatoe crops have been raised by it in some parts of Lancashire.

OIL-Compost, a substance of the manure kind, prepared by incorporating different oily materials with those of other kinds. It has been highly extolled by some cultivators, while others have thought less favourably of its properties. It is probable, however, that the expense of articles of this nature must render their use very limited in most situations.

But on the supposition that oil rendered miscible with water, constitutes the chief nourishment of vegetables, and affords their principal support; Dr. Hunter of York proposed the following oil-compost.

	£.	s.	d.
Take North American pot-ash 12lb.	0	4	0
Break the salt into small pieces, and put it into a convenient vessel with four gallons of water. Let the mixture stand forty-eight hours, then add coarse train-oil, 14 gallons	0	14	0
	<hr/>		
	0	18	0

It may be noticed, that in a few days the salt will be dissolved, and the mixture, upon stirring, become nearly uniform. Then take fourteen bushels of sand, or twenty of dry mould. Upon these pour the above liquid ingredients. Turn this composition frequently over, after adding to it as much fresh horse-dung as will bring on heat and fermentation: in six months it will be fit for use. And it is apprehended, that the above quantity will be found sufficient for an acre; his trials, however, do not give him sufficient authority to determine upon this point. But for the convenience of carriage, he has directed no more earth to be used than will effectually take up the liquid ingredients. However, if the farmer chooses to mix up the compost with the mould of his field, he would advise him to use a larger portion of earth, as he will thereby be enabled to distribute it with more regularity upon the surface. He has not yet had any extensive trial of its efficacy upon pasture and meadow grounds; but he presumes, that whatever will nourish corn, will also feed the roots of grafs. When used upon such lands, it should be put on during a rainy season, as all top-dressings are injured by the solar heat, and all kinds of cattle must be kept off the lands for some time, as they will bite the grafs too close in quest of the salt contained in the compost, which he has found to be the case in small trials.

It is added, that the oil-compost is only intended to supply the place of rape-dust, foot, woollen rags, and other

expensive hand-dressings. It is in all respects inferior to rotten dung: where that can be obtained, every kind of manure must give place to it. But at the same time that dung affords nourishment, it opens the pores of the earth. Hand-dressings, on the contrary, give food to plants, but contribute little towards loosening the soil. This is an useful and practical distinction, and may be applied through all the variety of manures made use of by the farmer. And it is presumed, that the oil-compost resembles the natural food of plants; but he submits that, as well as every thing else, to experience our unerring guide. It may be objected, that it has not sufficiently undergone the putrid ferment, to attenuate the oily particles. The use of rape-dust, foot, horn shavings, and woollen rags, takes off that objection, and at the same time confirms the theory upon which the above compost is founded. But he does not take upon him to direct the experienced farmer in the manner of using this new compost. He would have every person apply it in the way most agreeable to himself. Many things will occur to the practical husbandman, that no reasoning of the philosopher could foresee. By attending to the different ways of using it, we may, it is supposed, reap considerable advantages. Improvements may be collected even from the highest degree of mismanagement. And facts must ever be the foundation of our reasoning. Without them, the philosopher is a kind of *ignis fatuus*. Instead of unfolding nature, he covers her with a cloud, and endeavours, as it were, to bring old chaos back again into the world. If, however, he should presume to instruct the farmer in the management of the compost, he would recommend it to be sown immediately after the grain, and both harrowed in together.

The following experiment is stated, which, though trifling in its own nature, gave him the first encouragement: to prosecute the subject upon a larger scale. He took four pots, Nos. 1, 2, 3, 4.

"No. 1. contained 12lb. of barren sand, with 1 oz. of the sand oil-compost.

"No. 2. contained 12lb. of sand without any mixture.

"No. 3. contained 12lb. of sand, with $\frac{1}{4}$ oz. of slaked lime.

"No. 4. contained 12lb. of sand, with 4 oz. of the sand oil-compost."

And in the month of March he put six grains of wheat into each pot, and during the summer occasionally watered the plants with filtered water. All the time that the plants were consuming the farina, he could observe but little difference in their appearance. But after one month's growth, he remarked that No. 1. was the best; No. 2. the next; No. 3. the next; No. 4. much the worst. And in August he made the following observations: No. 1. had five small ears, which contained a few poor grains. No. 2. had three small ears, containing a few grains, much inferior in goodness to the former. No. 3. had no ears. Only he observed two very small ones within their respective sheaths, which for want of vegetable strength never made their appearance. No. 4. had no ears; the stalks appeared stunted in their growth.

"He then removed the plants from their pots, and took a view of the roots of each.

"No. 1. The roots tolerably large, and well spread.

"No. 2. The roots not so large.

"No. 3. The roots very short and small.

"No. 4. The roots much the shortest, with the appearance of being rickety."

Upon this experiment it is suggested,

"1. That the oil-compost may be considered as a vegetable food; but, 2. when used too liberally, the alkaline

salt will burn up the roots of the plant, and hinder vegetation. For which reason he would recommend the compost to be exposed to the influence of the air for some months, before it is laid on. 2. That lime contains no vegetable food, and is, in its own nature, an enemy to vegetation. It is, however, of excellent use in assisting vegetation."

These experiments teach him, that all kinds of soils may be benefited by this manure. The limestone, gravelly, sandy, and chalky soils seem to require it most. The rich loams and good clays have nourishment within themselves, and stand more in need of the plough than the dung-hill. And it is noticed, that it is observed by farmers, that rape-dust seldom succeeds with spring-corn, unless plentiful rains fall within a few weeks after sowing. He has more than once made the same observation upon the oil-compost, which induces him to recommend it for winter crops only. From the unctuousness of its nature, it is more than probable, that it should lie exposed for a long time to the influence of the weather, which benefit it is deprived of when used for barley, and such crops as are sown late in the spring. He is confirmed in this idea, from repeated experiments made with the compost upon turnips, which generally proved unsuccessful. And at the same time he invariably found that those parts of the field on which the compost had been spread produced the best crops of grain the following year. From this slow manner of giving its virtues, it seems to be an improper dressing for all plants that have a quick vegetation.

On the whole it is concluded, that the oil-compost, as it plentifully restores particles of the oily kind, similar to those that are carried off, has a fair appearance of proving an excellent restorative.

The following experiments in support of the utility of this sort of manure are stated. In the month of June he selected four lands of equal goodness in a field intended for turnips. The soil was a light sand, with a small portion of vegetable earth amongst it. It was ploughed out of sward in November, and had not borne a crop for many years. He distinguished his experimental lands by Nos. 1, 2, 3, 4.

No. 1. was manured with rotten dung.

No. 2. with oil-compost.

No. 3. with lime.

No. 4. was left without any dressing.

On the 20th of June they were all sown with turnip-seed, broadcast, and during the course of the season were twice hoed.

"In November he viewed the field, and made the following remarks:

N^o 1—the best.

2—the next.

3—the worst.

4—better than N^o 3.

"Here he supposes the oil-compost appears in a favourable light; but other trials, made with equal accuracy, seem rather to prove that it is not proper for turnips, barley, or quick growing vegetables. It requires being meliorated by the action of the atmosphere, and therefore is better adapted to winter crops." But by repeated experiments made since he first brought forward this manure, he is "convinced that the addition of an alkaline salt is not sufficient to alter the nature of soil, so as to make it fully capable of entering in to the roots of plants in its native form: but when decomposed by the mixture of fresh dung, he is convinced that it then becomes the true pabulum of plants."

It is supposed that "when the land happens to be stiffer than is required for turnips, it may be good husbandry to lay upon it a large quantity of lime to open its body for the free admission of the tap-root of the turnip. The lands will

also be rendered more dry, without which the turnips will never arrive at any size. Farmers, in general, take great pains to pulverize their light soils intended for turnips; but they seldom plough deep enough. A turnip is found to root deep, and in all operations of husbandry we should be careful to follow the bias of nature. It is for that reason we ought to make ourselves acquainted with the size and the shape of the roots of such plants as are the objects of field husbandry: when once we have obtained that necessary knowledge, it will be an easy matter to suit the preparation of the soil to the nature of the grain. It will also enable us to direct the variations of our crops upon just and rational principles."

But in Mr. Stovin's trials with oil-compost in 1769, the results were these:

	£	s.	d.	Q.	B.	P.
"One acre, sown with barley, and manured with oil-compost -	0	18	0	5	5	0
"One acre adjoining, sown with barley, and manured with rotten dung, twelve loads, worth -				4	3	
Difference				1	1	2

And the compost barley was bolder and better corn than the other. In the year 1770, the dunged acre produced of rye, three quarters. The compost acre, of ditto, two quarters six bushels. And in the year 1771, the same lands were sown with oats, and the produce was greatly in favour of the dunged acre. This last experiment, being contrary to the idea of good husbandry, was made with a view to determine the absolute strength of the compost. All top-dressings are exhausted in the year. The oil-compost seems to retain its vigour longer. It will here be proper to observe, that these experimental lands were in a common field, which had been many years under the plough.

Also in Mr. Townley's experiments, they were as below. "In the spring of 1770, he prepared a piece of ground for onions. It was laid out into six beds of equal size, and all sown at the same time.

"Over two of them, the oil-compost was scattered in a very moderate quantity; over the other two, pigeon-dung; and over the remaining two, some of his weed-compost, which he esteems one of the best manures, for most vegetables, that can be made." It is composed of vegetable substances reduced into a putrid state. "The onions came up very well in all the beds; but, in about six weeks, those that were fed with the oil-compost plainly distinguished the advantage they had over the rest, by their luxuriance and colour; and at the end of the summer perfected the finest crop that he had ever seen, being greatly superior to the others both in quantity and size."

In another experiment with it in this crop, his success was still much greater though the soil was worn out. The oil-compost was used as a top-dressing after the crop was sown. "The same spring he made an experiment upon four rows of cabbages, set at the distance of four feet every way. Two were manured with the oil-compost, and two with his own. All the plants were unluckily damaged, just before they began to form, by some turkeys getting into the field, and plucking off the greatest part of the leaves. However, they so far recovered as to weigh, in the September following, from 22lbs. to 28lbs. a-piece. The rows proved so equal in goodness that he could not determine which had the advantage."

And "the same year one part of a field of wheat ex-

posed to the north-east winds, which that spring continued to blow for a month or five weeks, appeared very poor and languid at the time of tillering. Over it he ordered some of the oil-compost to be sown with the hand, which not only recovered, but also pushed forwards the wheat plants in that part of the field, so as to make them little inferior, if any, to the rest."

The same spring he "made a comparative experiment upon four contiguous lands of oats, between the oil-compost and his own weed-compost. The latter had manifestly the advantage, though the other produced a very fine and large crop. He also tried the oil-compost upon carrots, and it answered exceedingly well. He did the same this year (1771), both upon them and his onions; and has the finest crops of those vegetables he ever saw any where upon the same compass of ground."

Mr. Roebuck, in trying this manure in gardening, planted twelve alleys, that lay between his asparagus beds, with cauliflower plants; each alley took up about thirty plants. One of the alleys he set apart for an experiment with the oil-compost, prepared as above.

"About a handful of the compost was put to the root of each cauliflower plant. In all other respects the alley was managed like the rest. The plants in general flowered very well; but those to which he applied the compost, sprung up hastily with small stalks, and produced very poor flowers. He imputed this unfavourable appearance to the freshness of the compost, which was only a few weeks old. In all future trials, he intends to expose it to the action of the air, in order to abate the heat, and neutralise the acrimony of the salt."

But "in the September following this unsuccessful experiment, he planted the same alleys with early cabbages. The necessity of meliorating the compost was in this trial fully confirmed. For the cabbages that grew upon the alley, which in May had received the compost, were larger, and in all respects finer, than the others. The idea that he entertains of the compost is, that when meliorated in the earth, it is capable of giving a richness and freshness to it. Upon this principle he would recommend it to gardeners as a subject worthy of further trials.

Although these experiments sufficiently shew, that substances of this sort may be used with advantage in the way of manures, their expence must in most cases prevent their being made use of to any great extent.

OIL-MANURE, such as is constituted of oil with other materials. The composition of a manure of this kind, which has been said to be highly beneficial, with the expence for one acre of land in 1792, is thus stated:

	£	s.	d.
Rape or train-oil six gallons, at 2s. 6d.	-	0	15 0
Sea-sand six bushels, at 2d.	-	0	1 0
Coarse salt two bushels, at 1s.	-	0	2 0
Malt coombs 24 bushels, at 4½d.	-	0	9 0
		1	7 0

In the preparation of which, it is advised to spread the coombs on the floor about four inches thick, then to sprinkle the salt as level as possible, throwing on half the quantity of sand and half the quantity of oil out of a watering-pot, turning it and raking it well, afterwards to add the rest of the oil and sand as before, turning it well till thoroughly mixed, and then throw the whole into a heap for use. On this it is suggested, that as the prolific quality of oil-cake is only in proportion to the oil it contains, this composition must be preferable, having a much greater quantity of oil

in it; and as malt coombs are a manure of themselves, especially for turnip land, at about eighty or ninety bushels *per acre*, he dares venture to assert, that twenty-four bushels with the addition of oil is equal to the above quantity, or even to the twelve loads of muck. The sand and salt mixed with it, not only occasion it to imbibe the oil more freely, but likewise give it a better body for the conveniency of spreading on the land. And though some may think the quantity of salt is too little, he is convinced of the contrary, having found by experience that a ton or even a ton and a half has not answered so well as three or four hundred. The case is very similar with regard to lands near the salt marshes, where the tide sometimes overflows them, and it is well known by those who occupy such lands that nothing will grow for three or four years, but afterwards they become very fertile. The reason he shall not take upon himself to give, but he has found it so by his own experience. The writer concludes by observing, that some farmers have used only half the above quantity *per acre*, notwithstanding which they had good crops. But it has been observed that the extra expence makes against its becoming generally useful from the great price of oil, and the expence of the carriage of sea sand and dross salt, in most inland situations. See *OIL-Compost*.

OIL-Paint, in *Rural Economy*, that sort of paint which is composed of oil, and the oxyd of lead, or some other similar substance, to form its basis, or give it a body, and which is used for various farm purposes.

But the great expence of paints of this sort has led lately to the introduction of many other materials, for the protection of wood work, and boarding of different kinds, such as preparations from fossil coal, &c. But a great objection to all these substances, besides their expence, is the highly disagreeable smell that they afford, and their liability to crack and blister.

In cases where oil painting cannot be had recourse to, either because it does not dry soon enough, and has an insupportable smell, or because it is too dear; the following method has been employed by Mr. Ludicke for painting ceilings, gates, doors, and even furniture, with great success: it is thus prepared, take fresh curds, and bruise the lumps on a grinding-stone, or in an earthen pan, or mortar, with a spatula. After this put them in a pot with an equal quantity of lime, well quenched, and become thick enough to be kneaded; stir this mixture well without adding water, and a white coloured fluid will soon be obtained, which may be applied with as much facility as varnish, and which dries very speedily. It must, however, be employed the same day, as it will become too thick the next day. And with this ochre, armenian bole, and all colours which hold with lime, may be mixed according to the colour which is wished to be given to the wood; but care must be taken that the addition of colour made to the first mixture of curds and lime contain very little water, otherwise the painting will be less durable.

In performing the work, after two coats of this paint have been applied, it may be polished with a piece of woollen cloth, or other proper substance, and will become as bright as varnish.

It is asserted that this paint, besides being cheap, has other advantages; in the same day two coats may be laid on and polished, as it dries speedily, and has no smell. If it be required to give it more durability in places exposed to moisture, it may be done after it has been polished with the white of an egg; which is said to render it as durable as the best oil painting that can be employed. And another substitute that may be used for painting weather boarding is

prepared by taking three parts air-slaked lime, two of wood-ashes, and one of fine sand or sea-coal ashes, sifting them through a fine sieve, and then adding as much linseed oil as will bring it to a consistence for working with a painting brush: great care must be taken to mix it perfectly. It is impenetrable to water, and the sun hardens it, and renders it a great preserver of the wood.

Another composition has likewise been made use of with great benefit to paint boards, &c. which is made in this way. Melt twelve ounces of rosin in an iron pot, adding three gallons of train oil, and three or four rolls of brimstone; when melted thin, as much Spanish brown ochre first ground fine with as much of the oil as will give the colour, should be added; it should be laid on with a brush as hot and as thin as possible, and some days after the first coat is dry another applied. It will preserve planks for a very great length of time, as well as other substances.

The kinds of oils, their properties, manners of expression, &c. are numerous: for the generality of them, the reader is referred to the proper articles.

Such as could not be more conveniently inserted, are as follow.

OIL of the Almond, in the *Materia Medica*, is obtained either from the sweet or the bitter almond, that from the one or the other being equally free from bitterness. The almonds are put into a coarse hempen or hair sack, and shaken violently, in order to detach, by friction with one another and against the sides of the sack, the outer-brown skin, which is apt to give a bitter taste to the oil: they are then bruised and made into a paste, and pressed in the usual manner. The London college directs the almonds to be macerated in cold water for 12 hours, and then bruised; and the oil is afterwards to be expressed without heat. The Edinburgh college orders any quantity of almonds to be bruised in a stone-mortar, and then put into a hempen sack; the oil is to be expressed without heat. The Dublin college prepares this oil by bruising the fresh almonds in a mortar, and expressing it by a press, without heat. Sixteen ounces of almonds yield about five ounces of a bland inodorous oil, of a very slightly sweetish taste, which is at first turbid, but soon becomes clear. About 3iii more may be obtained by impregnating the marc with the steam of boiling water. The colour of this oil is very pale greenish-yellow, and its specific gravity .932, Fabroni; .917, Aikin. The degree at which it congeals is variously stated at 19° Fahr. and 8° Fahr. It is said that the oil from the bitter almond keeps longer without growing rancid than that from the sweet almond. This oil is demulcent and emollient, and used in coughs and other pulmonary complaints united with water by means of mucilage, or the yolk of egg and sugar. A mixture of f. 3iv of almond oil, m. viii of acetate of lead, forms an useful injection at the commencement of gonorrhœa. The dose of the oil is from f. 3iv to f. 3j. See *ALMOND*.

OIL of Amber of the London college is obtained by putting the amber into an alembic, and distilling from a sand-bath, with a fire gradually raised, an acid liquor, the oil, and a salt impregnated with the oil; then re-distilling the oil twice.

The *purified* oil of amber of the Edinb. dispensatory is had by distilling oil of amber, mixed with six times its weight of water, from a glass retort, until two-thirds of the water have passed into the receiver; then separating this purified volatile oil from the water, and keeping it in well stopped vessels.

The *rectified* oil of amber of the Dublin pharmacopeia is prepared by taking a pound of the oil which comes over in the preparation of succinic acid, and six pints of water, and

distilling until two-thirds of the water have passed into the receiver, and separating the oil. This oil is of a dark colour, thick consistence, and fœtid odour; but by successive distillations, it is rendered thinner, of a lighter colour, and at length nearly limpid. Rectified oil of amber has a strong ungrateful odour, and a hot acrid taste. It is light, volatile, and inflammable, insoluble in water, and only partially soluble in alcohol. As to its medical properties, it is stimulant, antispasmodic, and rubefacient. It has been found serviceable in deficient menstruation, and in hysteria, epilepsy, and some other convulsive affections; but it is now scarcely ever used as an internal remedy. The dose may be from $\mathfrak{m} \text{ v}$ to $\mathfrak{m} \text{ xj}$, combined by means of mucilage with any distilled water. It is more generally employed as a rubefacient in rheumatism and paralysis; and a mixture of $\mathfrak{f} \text{ ʒj}$ of this oil with $\mathfrak{f} \text{ ʒss}$ of tincture of opium, has been found beneficial as a friction to the affected part in tic douloureux; and in whooping-cough, rubbed upon the chest two or three times a day. The official preparation is the *SPIRITUS Ammonie Succinatus* of the London college. See AMBER and SUCCINIC Acid.

OILS, *Animal*, in general, are those that are obtained from animal substances, either in the state of butter and fat, uncombined with the other principles of animal matters; of which kind are fat, marrow, the expressed oils of yolks of eggs, spermaceti, &c. Or, in a state of combination, afforded by distillation of the gelatinous substance, which forms almost entirely all the parts composing animal bodies, as flesh, tendons, nerves, cartilages, bones, horns, hair, &c. See OIL, *supra*.

OIL, *Animal*, *Oleum Animale*, in a more restricted sense, the name of an essential oil distilled by a retort from blood, and formerly recommended as a powerful internal remedy in epilepsies, the gout, and other obstinate diseases.

It was originally used in Germany in these intentions. As an external, it may probably be of good service in removing fixed pains, hard tumours, &c. for it is extremely penetrating.

OIL, *Volatile, Animal*, or *Dippel's oil*. (See DIPPEL'S OIL.) If albumen or gluten be distilled at a dry heat, there arises, together with the ammonia and carburetted hydrogen, a quantity of fœtid black oil, which was the subject of various experiments, first by Dippel, a chemist of Berlin, and afterwards by Rouelle. From the concurrent labours of the enquirers, it appears that if this oil is rectified by three successive distillations from the surface of water, it becomes at length quite colourless and transparent; its odour is powerful, but somewhat aromatic, and it is nearly as light and volatile as ether. It contains a little ammonia, and hence changes the colour of syrup of violets green; it is sparingly soluble in water, and largely so in oils, ether, and alcohols. It combines both with acids and alkalies into imperfect soaps; it is very inflammable, and, like the vegetable essential oils, may be set on fire by strong nitrous acid. If exposed even to the light, it is partly decomposed, losing its transparency, and becoming of a brown colour. It was formerly employed in medicine; but is now wholly disused. Aikin's Dict.

OIL of *Anise-seed*. (See ANISE-SEED.) This oil is given as a carminative, and for relieving flatulence in children, from $\mathfrak{m} \text{ v}$ to $\mathfrak{m} \text{ xv}$ triturated with sugar. The official preparations are *tinctura opii ammoniata* of the Edinburgh college, and *tinctura opii camphorata* of the Dublin college. See TINCTURE.

OIL of *Antimony*, a name given to the butter of antimony, and some other solutions of antimony by acids. See ANTIMONY.

OIL of *Arsenic*. See ARSENIC.

OIL of *Aspic*, or *Spike*. See SPIKE.

OIL of *Balm*. See BALSAM and MELISSA.

OIL of *Bays* is an essential oil, obtained from the berries of the bay, or *LAURUS Nobilis*. These berries give out to the press an almost insipid fluid oil; and on being boiled in water, a thicker butyraceous one, of a yellowish-green colour, impregnated with the flavour of the berry. The berries and leaves of the bay are accounted stomachic, carminative, and uterine: with this view, infusions of the leaves are drank as tea, and the essential oil of the berries is given on sugar, or dissolved by means of mucilages, or in spirit of wine, from one to five or six drops. But the principal use of these simples in the present practice is external: they are made ingredients in carminative glysters, warm cataplasms, and uterine baths; and the butyraceous oil of the berries serves as a basis for some nervine liniments, and mercurial and sulphureous unguents. Lewis. See DAPHNE-LÆON.

OIL of *Beech*. See BEECH-oil.

OIL of *Ben*, or *Ben*. See BEN.

OIL, *Birch*, a vegetable empyreumatic oil, prepared in Russia, by charring birch-wood in a close oven, the watery acid and oil being collected in a large receiver; and the latter product being the lightest, is skimmed off from the surface of the water. This oil has a peculiar scent, and is said to drive away worms and other insects; on which account it is used in the dressing of Russia leather, to which it communicates those properties that render it so much esteemed by the binders of books.

OIL, *British*, an empirical medicine of the same nature with the petrolea; the genuine sort being extracted by distillation from a hard bitumen, or a kind of stone-coal, found in Shropshire, and other parts of England. Lewis.

OIL, or *Butter*, of *Cacao*. See COCOS.

OIL, *Cajeput*. See CAJEPUT and MELALEUCA.

OIL of *Camphor*. See CAMPHOR and LAURUS.

OIL of *Caraway*. (See CARUA.) Six pounds of caraway-seeds yield $4\frac{1}{2}$ ounces of oil, which has an aromatic odour, and a sweetish pungent taste; it is viscid, and of a yellow colour; its specific gravity is .946. This oil, which is stimulant and carminative, is chiefly used as an adjunct to purgative pills, and for covering the disagreeable flavour of other substances. The dose is from $\mathfrak{m} \text{ j}$ to $\mathfrak{m} \text{ x}$. The official preparations are electuary sennæ, confection scammonii, pilulæ aloes comp., and pilulæ aloes, cum myrrha.

OIL of *Castor*. See CASTOR and RICINUS.

OIL, *Cardamom*. See CARDAMOM.

OIL, *Caulic*. See ARSENIC.

OIL of *Chamomile*, an oil distilled from anthemis or chamomile. Its odour is unpleasant, and its taste pungent. When recently distilled, its colour is a cerulean blue, which changes by age to a deep yellow. Eighty-two pounds of chamomile-flowers yield 18 drams of oil. This oil is supposed to possess antispasmodic powers, and is therefore sometimes recommended in cramp of the stomach, and as an adjunct to purgative pills. The dose is from $\mathfrak{m} \text{ v}$ to $\mathfrak{m} \text{ x}$, but it is seldom used. See ANTHEMIS.

OIL of *Cinnamon*. See CINNAMON.

OIL of *Cloves*. See CARYOPHYLLUS.

OIL of *Cole-Seed*. See COLE-Seed.

This oil, and also those of mustard-seed, rape-seed, and sunflower-seed, are less coloured and less highly flavoured than those of linseed and hemp-seed. They are very little liable to dry by exposure to the air; and these circumstances, together with their moderate price, induce a large consumption of them by the wool-dressers, in order to pre-

serve the wool from the attacks of moths and other insects; and also by the leather-dressers.

OIL, Connecting, a term used by Boerhaave, and his followers, to express a certain oil, found in all vegetable substances, but wholly different from, and independent of, their essential oil. This is not possessed of any of their virtues or qualities, but seems the same in all plants, and is the means of their consistence and solidity, giving tenacity to their earth, which, without it, falls to dust, and the plant exists no more.

This oil is not separable by boiling water, as the essential oil is, but only by fire: when a plant has been boiled and distilled, its essential oil, salt, &c. are all carried off, and what remains is only the earth corrected by this oil. This being exposed to the fire, the oil discovers itself in a thick, black, stinking smoke, and, finally, taking fire, it burns away, and leaves only the earth, which was the basis of the plant; retaining its form, indeed, if the process has been carefully made, but falling into a shapeless powder only on being roughly breathed upon.

This great author, therefore, establishes it as a rule, that there are three sorts of oil in plants. 1. An oily froth. 2. The essential oil, dissolved in decoction. And, 3. This connecting, or consolidating oil, separable only by a naked fire.

OIL, Cornel. a fixed oil resembling olive oil, by being contained, not in the seed, but in the pulpy fruit of the vegetable. The berries of this shrub (*Cornus Sanguinea*) being collected when quite ripe, and laid in heaps for a few days to mellow, are to be reduced to a pulp, and pressed without heat in the usual manner. By this treatment, from 22lbs. avoirdupois may be obtained somewhat more than four wine pints of a fat, somewhat viscid, oil, of a bright green colour, and equally destitute of any unpleasant flavour as the best olive oil. When heated with nitric acid, it is converted to a brown-yellow butter or wax. By boiling with litharge, it becomes drying; when spread thin on water, and exposed to the air for a month, it is converted into a white wax. It does not freeze so readily as olive oil, and lasts rather longer than this when used in a lamp. Aikin's Dict.

OIL of Cumin. See CUMINUM.

OIL of Dill. See ANETHUM.

OILS, Drying. See OIL, *supra*.

Drying oils are formed of linseed oil, prepared by means of boiling, sometimes with and sometimes without the addition of other substances. Those commonly added to oil, in this preparation, are white vitriol, fugar of lead, seed-lac, gum mastic, gum sandarac, gum anime, gum copal, umbre, colcothar, litharge, and red-lead. A drying oil for the nicer works may be prepared by boiling two ounces of gum sandarac, white vitriol, and fugar of lead, of each one ounce in a pint of nut or poppy oil, till the solid ingredients be dissolved, and the mixture becomes of the colour of linseed oil. For coarser work, take one gallon of linseed oil, one pound of litharge of gold or silver, half a pound of white vitriol, and fugar of lead, gum arabic, and umbre, of each a quarter of a pound; boil them as long as the discolouring of the oil, which is the gradual consequence of boiling, will allow. That made for sale is prepared by boiling one gallon of linseed oil, and one pound and a half of red-lead, as long as the colour will bear it. When the calxes of lead are united in small quantity with oil, they diminish its fluidity, and dispose it to dry more readily. These oils are much used in painting, on account of their drying quality. When a large quantity of calxes of lead is combined with oil, they form with it a solid, opaque, and

tenacious body, capable of softening by heat. These combinations are useful in pharmacy, for giving a convenient consistence and tenacity to many plasters.

OILS, Distilled, are the volatile oils, so called in the London pharmacopœia. For preparing them, they direct that the seeds of anise and caraway, the flowers of chamomile and lavender, the berries of juniper and all-spice, the tops of rosemary, and the entire plants of the other articles, dried, are to be employed. Any one of these is put into an alembic, and as much water poured in as will cover it; and then the oil is distilled into a large refrigeratory. The water which distils over with the oils of pepper-mint, spearmint, all-spice, and penny-royal, is to be preserved for use.

OIL of the Earth, Oleum Terra, in the *Materia Medica*, the name of a thick mineral fluid of a dusky brownish-black, with a faint cast of purple, and of the consistence of a thin syrup, very little transparent, and of a strong penetrating smell, like that of common oil of amber. It oozes out of the cracks of rocks, in several parts of the island of Sumatra, and some other parts of the East Indies, and is much esteemed there in paralytic disorders; but it is seldom imported into England; what our East India surgeons and captains usually bring over under this name being only a vegetable oil, impregnated with the virtues of certain of their fossils by boiling. See PETROL.

OIL, Empyreumatic. See OIL, *supra*, and EMPYREUMA.

OILS, Essential, are those which have evidently the smell of the vegetable from which they are obtained. All these oils are sufficiently volatile to rise with the heat of boiling water; and this degree of volatility is one of their specific characters. See OIL, *supra*.

The oils of plants have not always the same tastes with the plant they are distilled from, or, at least, not in the same degree. Nothing is more bitter than wormwood, yet the oil of wormwood has no remarkable bitterness. Anise, which is of a sweet taste, yields, on the contrary, an oil infinitely more sweet than the seed; and pepper, which is so remarkably hot and acrid, affords an oil no way remarkable for its pungency. Thyme, which is in itself very acrid and pungent, conveys that property, in a yet greater degree, to its oil; there is, indeed, no essential oil so acrid and fiery as that of this plant. The fetid oils drawn in dry distillation by the retort, in an open fire, no way differ from these but by the damage the fire has done them, and may always be converted into these by repeated distillations. Nay, the very fat oils, such as that of almonds, may be attenuated so far as to become as fine, and as subtle, as the essential oils. This is to be done by means of quick-lime; and several repeated distillations of this oil, or any other of a like kind, with fresh lime to every distillation, will reduce it to be volatile, penetrating, and capable of being raised, and distilled, by means of water, which is the greatest test of the essential oils. The bituminous and fetid oils may also, in the same manner, be reduced, by repeated distillations, to the state of the essential ones, and to be equally fluid and limpid, and equally penetrating. *Memoirs Acad. Par. 1721.*

The essential oils of vegetables may be divided into two classes, according to their different specific gravities, some floating upon water, and others readily sinking to the bottom thereof. Thus the essential oils of cloves, cinnamon, and saffras, readily sink; but the oils of lavender, marjoram, mint, &c. swim upon the water. The lightest of all the essential oils is, perhaps, that of citron peels, which even floats on spirit of wine; and the heaviest of them seems to be the oil of saffras.

For the obtaining the full quantity of the more ponderous

oils from cinnamon, cloves, saffraſas, &c. it is proper
 1. To reduce the ſubjects to fine powder. 2. To digeſt this powder for ſome days in a warm place, with thrice its quantity of ſoft river water made very ſaline with the addition of ſea-falt, or ſharp with oil of vitriol. 3. To uſe the decoction left in the ſtill, inſtead of common water, for a freſh digeſtion. 4. To uſe alſo, for the ſame purpoſe, the water of the ſecond running, after it has been cleared of its oil. 5. Not to diſtil from too large a quantity of the ſubject at once. 6. To leave a conſiderable part of the ſtill empty. 7. To uſe a brisk fire, or a ſtrong boiling heat at firſt, but to ſlacken it a little afterwards. 8. To have a low ſtill head, with a proper internal lodge, and current, leading to the noſe of the worm. And, 9. To colubate the water, or pour it back upon the matter in the ſtill, after ſeparating its oil, and repeating this once or twice more.

The vegetable world affords vaſt variety of eſſential oils, moſt of them very odorous, and of great virtues; but different vegetables yield oils of different conſiſtence, and in different quantities.

Theſe oils are employed in painting, in ſpirituſous liquors uſed at the table and at the toilette, in perfumes, and in medicine. As they act very powerfully, ſmall doſes, as from one drop to four or five, incorporated with ſugar, muſt be given internally. They are recommended as cephalic and antipafmodic, in convulſive and hyſterical affections: they are alſo ſtimulant, ſudorific, and ſtrengthening. All drugs which are alexipharmic, cephalic, tonic, and ſtomachic, containing vegetable aromatic, derive their virtues from the eſſential oils of theſe vegetables. The ſame may be ſaid of all medicinal, aromatic, and ſpirituſous waters. In ſome caſes, eſſential oils are employed externally as ſtrengtheners, and to allay painful ſpaſms of nervous and tendinous parts, to reſolve and diſſipate acrid humours, which occaſion pain, without any ſenſible inflammation; but they muſt not, on account of their cauſtic quality, be uſed alone, but formed into liniments or pomatums, by mixing them with a ſufficient quantity of fat, or fat oils. When applied to the human body, they ſtimulate, corrode, and reſiſt putrefaction; and mixed with the blood, raiſe ſome degree of fever. Med. Eſſ. Edinb. vol. v. art. 24. See *Volatile OILS, infra*.

As many of the eſſential oils are dear, it is a very common practice to adulterate, or debaſe them ſeveral ways, ſo as to render them cheaper both to the ſeller and the buyer. Theſe ſeveral ways ſeem reducible to three general kinds, each of which has its proper method of detection. Theſe three ways are, 1. To adulterate them with expreſſed oils. 2. With alcohol. And, 3. With cheaper eſſential oils.

If any eſſential oil be adulterated with expreſſed oil, it is eaſy to diſcover the fraud by adding a little ſpirit of wine to a few drops of the ſuſpected eſſential oil, and ſhaking them together; for the ſpirit will diſſolve all the oil that is eſſential, or procured by diſtillation, and leave all the expreſſed oil that was mixed with it untouched.

If an eſſential oil be adulterated with alcohol, or rectified ſpirit of wine, it may be done in any proportion, up to that of an equal quantity, without being eaſily diſcoverable either by the ſmell, or taſte. The way to diſcover this fraud is to drop a few drops of the oil into a glaſs of fair water; and if the oil be adulterated with ſpirit, the water will immediately turn milky, and by continuing to ſhake the glaſs, the whole quantity of ſpirit will be abſorbed by the water, and leave the oil pure at top.

Finally, if an eſſential oil be adulterated by a cheaper eſſential oil, this is commonly done very artfully: the method is to put fir-wood, turpentine, or oil of turpentine, into the ſtill, along with the herbs to be diſtilled for their oil, ſuch as

roſemary, lavender, origanum, &c.; and, by this means, the oil of turpentine diſtilled from theſe ingredients comes over in great quantity, and is intimately blended with the oil of the genuine ingredient. The oils thus adulterated always diſcover themſelves in time, by their own flavour being overpowered by the turpentine ſmell; but the ready way to detect the fraud is to drench a piece of rag, or paper, in the oil, and hold it before the fire; for thus the grateful flavour of the plant will fly off, and leave the naked turpentine ſcent behind. Shaw's Lectures, p. 145.

The eſſential oils, as volatile oils are called by the Dublin college, are prepared in the following manner: let the oil be extracted by diſtillation from the ſubſtance previously macerated in water, as much water being added during the diſtillation as may be ſufficient to prevent empyreuma. In diſtilling fennel, pepper-mint, ſpear-mint, penny-royal, and all-ſpice, the watery fluid that comes over in diſtillation with the oil is to be preferred for uſe.

OIL of Fennel Seeds. (See *ANETHUM Faniculum*.) Seventy-five pounds of fennel ſeeds yield thirty ounces of oil, which is colourleſs, and congeals at 50°. It has the odour of the plant and a ſweet taſte. The ſpecific gravity is .997. The medical properties and uſe are the ſame with thoſe of the plant. The uſual doſe is from \mathfrak{m} ij to \mathfrak{m} xx; but it is rarely uſed.

OIL, Fern. See *FERN*.

OIL, Granulated, is that fixed in little grains; this is the beſt, and moſt eſteemed, eſpecially of oils of olives.

OIL, Green, Oleum Viride, a form of medicine preſcribed in the late London pharmacopeia, and made in the following manner: take leaves of bay, rue, marjoram, ſea-worm-wood, and chamomile, each three ounces; oil of olives, a quart. Boil the herbs in the oil till they are criſp, and then ſtrain off the oil; and when it has ſtood for the ſcæces to ſubſide, put it up for uſe.

OIL of Hartſhorn, Rectified, is prepared by the Dublin college in the following manner. Take of the oil which riſes in the diſtillation of the volatile liquor of hartſhorn, three pounds, and ſix pints of water. Diſtil the oil, then remix it with the water, and rediſtil, repeating the diſtillations until the oil becomes limpid. This oil ſhould be kept in a dark place, in ſmall phials completely filled and cloſely ſtopped.

This empyreumatic oil is firſt formed by the decomposition of animal matter by heat; and ariſes from a new combination of part of the hydrogen and carbon of the ſubſtance diſtilled. When firſt obtained, it is thick, of a dark colour, and has a very offensive odour; but by the rectification preſcribed, it is rendered thinner and leſs offensive. The rectified oil is nearly colourleſs and transparent; it has a ſtrong, ſlightly aromatic odour, and a penetrating taſte. It is very light and volatile, ſtrikes a green colour with ſyrup of violets, is partially ſoluble in water, and unites readily with alcohol, ether, and oils. The acids form with it a thick ſaponaceous compound; and with the alkalis it forms a fine ſoap. Expoſure to light and air deſtroys its transparency, and gives it a deep brown colour. As to its medical properties and uſes, this oil is ſtimulant, antipafmodic, anodyne, and ſudorific. It was formerly regarded as a remedy of much efficacy in fever, adminiſtered a few hours before the acceſſion of the paroxyſm of intermittents; and was alſo much employed in epilepsy, hyſteria, and all convulſive affections: but it is now almoſt diſcarded from practice, being only uſed occaſionally as an external application to paralytic limbs. The doſe may be from \mathfrak{m} x to \mathfrak{m} xxx, in a ſufficient quantity of water. Thomson's Lond. Diſp.

OIL, Hempseed, is of a green colour, and strongly impregnated with the peculiar colour of this plant. The proportion of oil which hemp-seed affords is from 20 to 25 *per cent.* In its general properties, uses, and mode of preparation, it very much resembles linseed oil; which see.

OILS, Inflammability of. See *OIL, supra.*

OIL of Juniper, or of Juniper Berries. (See *JUNIPERUS.*) Forty-eight pounds of berries yield six ounces of oil, of a specific gravity .611. In odour it resembles turpentine, and its taste is hot and acrid. It has a greenish-yellow colour, is viscid, and deposits a faculent matter when long kept. When genuine it is soluble in alcohol. This oil is carminative, diaphoretic, and diuretic. It is sometimes given in dropsy, and may be added to fox-glove, when it is exhibited in form of pills. The dose is from ℥j to ℥x, combined with water by means of sugar or mucilage.

OIL of Lavender. (See *LAVANDULA.*) One pound and nine ounces of this oil are obtained from eighty pounds of lavender flowers. Its odour is very fragrant, and taste warm and agreeable; its colour is a pale lemon-yellow, and specific gravity .936. It is stimulant and cordial; and is chiefly used in hysteria and nervous head-ache, in doses from ℥j to ℥v, given on a lump of sugar. Its official preparation is unguentum sulphuris of the Edin. pharmacopeia.

OIL of Lead, is a solution of salt of lead in the essential oil of turpentine. This preparation is a powerful antiseptic.

OIL of Lemon, called the essence of lemon. (See *LEMON.*) This essential oil is chiefly used as a perfume to cover the smell of sulphur in ointments compounded with it. Its official preparations are spiritus ammoniac aromaticus, unguentum sulphuris, and unguentum veratri.

OIL of Linseed. (See *LINSEED.*) The seeds of the common flax, consisting of a white kernel covered with a thin brownish shell, which cannot be separated from it, are submitted entire to the press; but if they are thus treated without any previous preparation, they yield a comparatively small quantity of oil, on account of a strong mucilage that resides in the shell, and absorbs a large proportion of the oil as it is forced out of the kernel. For this reason, and also because the cold-drawn oil is not so fit for the purposes to which this oil is generally applied, the mucilage is destroyed before the application of the press by the following method. An iron-vessel, like a sand-bath, and capable of containing some bushels, is fixed in a furnace; it is then filled with linseed, and heated by a moderate fire, the contents being carefully stirred from time to time, till every part may be equally roasted: at first there arises an abundance of aqueous vapour, which, as the heat is increased, is followed by dense blackish fumes of a very nauseous odour. When the torrefaction is completed, the paste is pressed in the mill in the usual way. The proportion of oil yielded by this trial is about 20 *per cent.*; its specific gravity is .9403; it is not congealed except by a cold below 0° Fahr., and its point of ebullition is about 600° of the same thermometer. The cold-drawn oil has a high yellow colour, is very unctuous and unpleasant both to the taste and smell: by exposure to the air and light it becomes dry. The hot-drawn oil is of a high yellowish-red, or deep wine colour, and is more nauseous than the former: it is of a thicker consistence, and dries without much difficulty in the air, more especially if it has been boiled with a little litharge. The great demand for this oil is in the coarser kinds of painting, particularly such as is not much exposed to the weather, as floor-cloths, &c. In medicine it is considered as emollient, demulcent, and slightly laxative; but as an

internal remedy it is seldom used, on account of its nauseous taste; though it has been given with advantage in ileus, when purgatives have failed. It is chiefly employed in the form of a glyster, in flatulent colic attended with costiveness, and in abrasions of the rectum; and it is an useful application to burns, especially when combined with lime-water. The dose, when taken by the mouth, is from f.ʒss f.ʒij; but from f.ʒij to f.ʒvj may be given at once, per anum. The official preparation is the linimentum aquæ calcis of the Edinburgh pharmacopeia, formed by mixing equal parts of linseed oil and lime-water. Aikin. Thomson

OIL of Mace. See *MACE* and *NUTMEG.*

OIL of Marjoram. See *MARJORAM.*

OIL, Medullary. See *MEDULLARY System.*

OIL of Mercury, a solution of corrosive sublimate in spirit of urine. See *MERCURY.*

OIL of Mint. See *MENTHA.*

OIL of Mustard. See *HEDGE MUSTARD,* and *SINAPIS.*

OIL of Myrrh. See *MYRRH.*

OIL of Nut. (See *NUT-OIL.*) As the walnut and hazel-nut from which this oil is obtained, chiefly by cold-drawing, come to their full perfection in the warm climate of the south of Europe, they will yield, by proper management, full half their weight of oil. Recent cold-drawn nut-oil is preferred by many to olive-oil, on account of its retaining the exquisite flavour of the nut; the hot-drawn has an empyreumatic taste, and is no longer fit for the table: it is, however, much valued by the painter, as being eminently drying, much less coloured than linseed oil, and capable of bearing the injuries of the weather better than any other oil.

OIL of Nutmeg. See *NUTMEG.*

OIL of Olives is the most popular, and most universal of all other; being that chiefly used in medicine, in foods, salads, and in the manufactures.

It is drawn from olives by presses or mills made for the purpose. The fruit is gathered when at its utmost maturity, in November, as it begins to redden: being put under the mill, as soon as gathered, care is taken that the mill-stones are set at such a distance that they may not crush the nut of the olive. The fleshy pulp, covering the nut or stone, and containing the oil in its cells, being thus prepared, is put into bags made of rushes, and moderately pressed; and thus is obtained a considerable quantity of a greenish semi-transparent oil, which, from its superior excellence, is called *Virgin oil.* The marc remaining after the first pressure is broken to pieces, moistened with water, and returned to the press, upon which there flows out a mixture of oil and water, which spontaneously separate by rest. This oil, though use for to the former, is of a good quality, and fit for the table. The marc, being again broken to pieces, well soaked in water, and fermented in large cisterns, is again submitted to the press, by which is obtained a very considerable quantity of a third kind of oil, that is very valuable to the soap-boiler and other manufacturers. In some countries, particularly in Spain, the olives, instead of being gathered by hand, are beaten down, so that the ripe and unripe ones are mixed together, and to these are added such as have fallen of themselves, and are therefore more or less decayed. All these are thrown together in a heap, which soon ferments: the olives in this state are ground and pressed, and thus is procured with less trouble a large quantity of oil, of a rank disagreeable flavour, which none can bear but such as have been accustomed to it from their childhood. Recently-drawn Virgin oil has a bland almost mucilaginous taste, with a slight but

agreeable flavour: when exposed to the air, in an open bottle or cask, a white fibrous albuminous matter is deposited, and the supernatant oil becomes clear and of a dilute yellow colour: and when this oil is poured off into another vessel, a second deposition occurs, and then the oil obtained, being put into clear glass phials, may be kept for a considerable time, without undergoing any change. But if the oil be allowed to stand on the white matter, it becomes in a few weeks very rancid; nor can the common oil, even under proper management, be preserved in casks longer than a year and a half, or two years at the farthest. The specific gravity of olive-oil is .9153; it boils at about 500° Fahrenheit, and congeals at 36° or 38° Fahrenheit. The facility with which it freezes renders it improper for lamps, especially in cold countries; but by previously exposing it in an open clear glass phial to the sun-shine, it may be so far amended in this respect, as to continue fluid at 21° Fahrenheit. Olive-oil is often sophisticated by a mixture of poppy oil, which renders it drying, a quality which the genuine oil does not possess. In countries that produce it, it is used for food, as butter is with us: that of the inferior kinds is burnt in lamps, or employed in the manufacture of soaps, which are of a finer quality than those that are composed of animal oils. The best oil is made in Provence; but that which we receive in this country is brought from Lucca and Florence. It is imported in jars, half-jars, and half-chests, which are wooden packages containing flasks.

Olive-oil is used in medicine, internally, as a demulcent in catarrh and other pulmonary affections, diffused in water by means of mucilage; and it is also given, in large quantities, to mitigate the action of acrid substances, as some poisons, taken into the stomach; and in cases of worms, applied externally it is a very useful relaxant, and instead of stopping up the cutaneous exhalants, appears to promote the excretion of sweat, on which account it is beneficially employed in frictions at the commencement of the plague. The body is ordered to be very briskly rubbed all over with a clean sponge dipped in warm olive-oil, and the operation is repeated once a day until symptoms of recovery appear. Mr. Jackson relates, that the coolies, who are employed in the oil-stores at Tunis, smear themselves all over with oil, and are seldom afflicted with the plague when it rages in that city. Frictions with it are useful in ascites. It is also used as an injection in gonorrhœa; as an adjunct to glysters in dysentery and intestinal abrasions; and extensively in pharmacy, in the compositions of ointments and plasters.

The dose of olive oil is from f. ʒss to f. ʒj, triturated with mucilage, or mixed with water by means of a few drops of solution of potash. In cases of poisons and worms, as much may be given as the stomach can bear. The official preparations of oil, besides cerates and ointments, are *Oleum sulphuratum*, L. E. *Linimentum ammoniæ fortius*, L. E. D. *Linim. ammoniæ carbonatis*, L. *Linim. calcis*, D. *Linim. camphoræ*, L. E. D. *Emplastrum plumbi*, L. E. D. *Emp. hydrargyri*, E. *Emp. oxidæ rubri ferri*, E. *Enema catharticum*, D.

For the "*oleum sulphuratum*," see preparations of SULPHUR. For the liniments, see LINIMENT. For the plasters, see EMPLASTRUM and PLASTER. Aikin. Thomson.

Oil of Orange-peel. See *AURANTI Cortex*.

Oil of Origanum. See *MAJORAM*.

OIL, Palm, or Oil of Senegal, a thick unctuous liquor, of a yellow colour, and a violet smell; so called, because drawn, by ebullition, or by expression, from the fruit of a kind of palm-tree, growing in several places of Africa, especially in Senegal.

Many of the palms produce nuts, which abound in oil.

The principal of these are the *Cocos Butyracea*, and *ELÆIS guineensis*. The ripe fruit is collected in a heap, and slightly fermented; it is then coarsely pounded and macerated in hot water, and thus its oil is parted with and swims on the surface of the water, which by cooling concretes into a solid cake. It is purified by washing in hot water, and thus becomes fit for use. It has a light brown-yellow colour, little or no taste, but a high odour and flavour like those of the Florentine iris; by long keeping it becomes rancid, and is then nearly white, and almost without odour.

The Africans and the Negroes in the West Indies use this oil as we do butter; and burn it in their lamps when old. With us, it is only used in some external applications, for pains and weakness of the nerves, cramps, sprains, and other such complaints. The common people sometimes apply it to chilblains; and when used early, not without benefit. It is also employed in the composition of the best yellow soap. It is sometimes counterfeited with wax, oil of olives, iris, and turmeric; but the trick is found out either by air or fire. The air alters the colour of the genuine, and leaves the counterfeit unchanged; and, on the contrary, fire changes the counterfeit, but does not alter the genuine.

OIL of Penny-royal. (See *MENTHA Pulegium*.) This oil, which is of a reddish-yellow colour, resembles in its other qualities the oil of pepper-mint. Its specific gravity is .978. It is stimulant and antispasmodic, but seldom used. The dose may be from ℥j to ℥v, given on a lump of sugar.

OIL of Jamaica Pepper. (See *PIMENTO*.) This oil has the agreeable odour of the pimento, with its pungent taste augmented. Its colour is reddish-brown, and it is heavier than water. It has the same properties with the all-spice, but in a greater degree: it is given in dyspeptic affections, colic, and tympanitis, in doses of from ℥ij to ℥v, rubbed with sugar, or in any proper vehicle. Its official preparation is *emplastrum aromaticum* of the Dublin college. See PLASTER.

OIL of Pepper-mint. (See *MENTHA*.) This is a common domestic remedy in cramp of the stomach, flatulent colic, and anorexia; and usually rubbed up with sugar or mucilage. The dose is from ℥j to ℥ij. The official preparations are *pilule thei camp.* E. *Pilule aloes cum zingibere*, D.

OIL of Petrol. See *NAPHTHA* and *PETROLEUM*.

OIL of Pimento. See *PIMENTO*, and *OIL of Jamaica pepper*, *supra*.

OIL of Black Pitch. See *PITCH*.

OIL of Poppy-seed, or Pink-oil, is extracted by cold-drawing from the seeds of the large white poppy (*Papaver somniferum*), which is largely cultivated for this purpose in France, the Netherlands, and various parts of Germany. It is transparent and nearly colourless, and when well prepared, has no other taste or flavour, than a slight one of nut-kernels. Its specific gravity is .9288. This is one of the naturally drying oils, and like all of that class is frozen with difficulty; it may be cooled down to 0° of Fahr, without congealing. When employed as food, it is scarcely to be distinguished from olive-oil, which is often adulterated with it. The quantity of oil yielded by a given weight of the seeds depends partly on the country and season in which the seeds are produced, and partly on the mode of extracting the oil. From 100lbs. of fresh seeds, some state the produce of oil at 25lbs., and others at 58lbs. It is used as an article of diet, and in the composition of varnishes, but it is very unfit for burning in a lamp. See *PAPAVER* and *POPPY*.

OIL of Rape-seed. See *RAPE*, and *OIL of Cole-seed*.

OIL, Red, in the *Porcelain Manufacture*, a name given to

a peculiar colour used on the china-ware, or to those pieces of the ware which are coloured with it. It is a very elegant ornament, and would be worthy our attempting to imitate in England, on our better sorts of wares. They do it in the following manner: they mix the red colour, called *tam-lan-hum*, or the copperas red (see PORCELAIN) with oil of stone, and with another oil, as they express it, of the same kind, made of a whitish sort of pebble, or agate, found on the shores of their rivers, and the place of which might probably be supplied with us by common crystal. The powder is to be thoroughly mixed with these liquors, and the vessel dipt carefully into the mixture, or some parts of it only covered with it in figures: after this, it is to be set by to dry, and, when thoroughly dried, it is to be baked in the common way. The general method is that of covering the vessel all over, both inside and out, with this red; and it comes out of the most bright and brilliant colour imaginable, but it will not ring when struck upon, as our common china-ware does. We seldom see this in any degree of perfection, but it is very elegant when fine.

OIL, Rock. See PETROLEUM.

OIL of Rosemary. (See ROSEMARY.) Twenty-four pounds of the plant yield one ounce of a fluid colourless oil, the odour of which is less agreeable than that of the plant. It deposits crystals of camphor when long kept. Its specific gravity is .934. As to its medical properties, it is stimulant, and frequently enters into the composition of liniments. The dose, as an internal remedy, may be from \mathfrak{m} ij to \mathfrak{m} vj; but it is scarcely ever ordered. The official preparations are tinctura saponis, and alcohol ammoniacum aromaticum.

OIL of Rue. (See RUTA.) Twenty-one pounds of rue yield 59 grains of oil, which has the strong ungrateful odour and taste of the plant. When recently drawn the colour is yellow, but it deepens into brown by age, and deposits a brownish resinous sediment. It congeals at 40° Fahr. Oil of rue is stimulant and antispasmodic; it is sometimes given in hysteria, and the convulsive affections of children attendant on dentition; and is also occasionally used as a rubefacient in palsy. The dose is from \mathfrak{m} ij to \mathfrak{m} v, triturated with sugar or mucilage.

OIL of Sage. See SAGE.

OIL of Sassafras. (See SASSAFRAS.) Sixty pounds of sassafras yield 12 ounces of a viscid yellow oil, heavier than water; its specific gravity being 1.094. Its odour is fragrant, and its taste hot and acrid, excoriating the lips when incautiously tasted.

The oil of sassafras is peculiarly liable to crystallization in certain circumstances, and that into the most beautiful forms. Mr. Maud gives an account of a quantity of this oil, which having stood exposed to the air in a very frosty night, in an open vessel, was in the morning found changed three parts in four of it into very beautiful and large crystals: they were of an hexagonal form, very transparent, and of three or four inches in length, and half an inch in thickness. These crystals subsided in water, and were insoluble in it; they were readily inflammable at the fire, and were reduced by heat to their pristine fluid state: hence it is evident that they still retain the natural qualities of an oil, though they appear under so very different a modification of their parts. What is most remarkable in this change, is, the metamorphosis of a fluid to a solid body, of so determinate and regular a figure, and that these crystals should be perfectly clear and colourless, though the liquor from which they froze was of a yellowish colour, not unlike that of Madeira wine.

This oil is stimulant, and supposed to be also sudorific and diuretic. It has been given in chronic rheumatism, scurvy,

and some cutaneous affections. The dose is from \mathfrak{m} ij to \mathfrak{m} x; but it is scarcely ever ordered.

OIL of Savine. (See JUNIPERUS.) Two pounds of savine are said to yield five ounces of oil, which is limpid, of a pale yellow colour, having the odour of the plant, and being very acrid to the taste. This oil is the principle on which the virtues of savine depend; hence it possesses the same properties, and is applicable to the same purposes as the plant. The dose may be from \mathfrak{m} ij to \mathfrak{m} vj, triturated with sugar.

OIL of Spearmint. (See MENTHA.) The flavour of this oil is similar to that of pepper-mint, but less grateful; its taste is warm, and less pungent; its specific gravity is .975, and its colour greenish. Its medical properties are the same with those of oil of peppermint. The dose is from \mathfrak{m} ij to \mathfrak{m} v, given on a lump of sugar. Its official preparation is infusum menthæ compositum, which is prepared, according to the directions of the Dublin college, by taking of the leaves of spearmint, dried, two drachms, and a sufficient quantity of boiling water to afford six ounces by measure when strained; digesting for half an hour, but straining the liquor when cold, then adding of refined sugar two drachms, oil of spearmint, three drops dissolved in half an ounce (fluid?) of compound tincture of cardamoms; and mixing the ingredients. This is a grateful stomachic, and is slightly diaphoretic. It may be serviceable in anorexia and nausea, and as a vehicle to cover the disagreeable taste of other medicines. The dose may be from f. 3j to f. 3iij, or at pleasure.

OIL, Stillatitious. See STILLATITIOUS.

OIL of Stone. In the manufacture of the Chinese porcelain, they use a liquid matter of a white colour, which they call by this name, on which their great mystery of finishing their work depends; yet this has been less enquired into by the imitators of that ware in Europe than many other articles of less consequence. The stone of which this oil is made, is of the same degree of hardness with that which the petunse is prepared of. They procure it from quarries, and choose such as is of a good white colour, and has many dark green spots in it.

These spots are of the colour of the leaves of cypress. Sometimes a stone is chosen which has a brown ground, variegated with spots and blotches of a reddish colour. They first carefully wash this stone; then laying it in a clean place, they break it to pieces with iron instruments, and afterwards grind these to a perfectly fine and impalpable powder, by rubbing them in large mortars, with pestles of stone faced with iron, and turned either by the labourers, or by water. When the whole is thus reduced to a fine powder, they throw it into a vessel of water; and stirring it briskly about, they let the coarser part subside to the bottom, and there swims a fine thick matter like cream, for two or three inches depth on the surface. This they carefully skim off, and putting it into another vessel, of clear water, they let it throw down any coarse matter it may yet contain; and, finally, taking off the thick surface again, they mix this with some fresh water in another vessel, and leave it to subside; then pouring on the clear water, they take out the remainder at the bottom of the vessel, which is perfectly fine, and resembles a thick cream. To every hundred pounds of this they add one pound of a substance of the nature of which we are not yet perfectly informed. It is said to be a mineral resembling alum. They calcine this first, and then beat it to a fine powder; and this being added to the cream, or oil, as it is called, serves to keep it always in the same liquid state. This substance, when finished in this manner, has very little title to the name of an oil; it is rather a varnish, and is always used in mixture with another varnish, which

is called at this time fern oil, and used to be called lime oil; it is prepared in the same manner with the other after burning. See *FERN-Oil*.

Oil of Sulphur is a name given to the concentrated acid of sulphur. See *OIL, supra*, and *SULPHUR*.

Oil of Tartar. See *TARTAR*.

Oil, Train. See *Whale FISHERY, TRAIN, and WHALE*.

Oil of Turpentine is obtained by distilling the resin with water in a common still, when the oil is found in the receiver swimming on the water, from which it is easily separated. The average proportion is 60lbs. of oil from 250lbs. of good turpentine. This process is carried on both abroad and at home; but the oil drawn in this country is always preferred. (See *PINUS*, and *TURPENTINE*.) The Dublin college directs 5lbs. of turpentine and four pints of water, and the oil to be distilled from a copper alembic. Yellow resin will remain in the retort after the distillation.

The rectified oil of turpentine of the London and Dublin college is obtained from a pint (two pints Dub.) of oil of turpentine, and four pints of water. Distil the oil (a pint and a half of the oil, Dub.)

Purified oil of turpentine of the Edinburgh college is obtained from 1lb. of oil of turpentine, and 4lbs. of water; and distilling as long as any oil passes over. The rectification of the oil is a troublesome process, and on account of the great inflammability of the vapours, much caution is required to prevent them from escaping through the luting of the vessels, and catching fire. The rectified oil is a little lighter than the common oil, and completely free from any resinous admixture; but in other respects it has no peculiar excellence to recommend it. What remains in the retort is a thick resinous matter, and is denominated "balsam of turpentine." (See *BALSAM*.) For the chemical and medicinal properties of oil of turpentine, see *PINUS, TURPENTINE*, and *TAPE Worms*.

Oil of Venus, a name given by Lemery to the salt formed by the union of copper with the nitrous acid, when it is resolved into a liquor by the moisture of the air. This is a caustic and escharotic.

Oil, Virgin, is understood of oils expressed from olives, nuts, &c. fresh gathered, without being heated, too much pressed, &c. See *OIL of Olives*.

Oil of Vitriol. See *SULPHURIC Acid* and *VITRIOL*.

Oils, Volatile. (See *OIL, supra*.) For the method of preparing these oils by the London college, see *Distilled OILS*, and for those of the Dublin college, see *Essential OILS, supra*. The Edinburgh college directs the volatile oils to be prepared in the same manner as the distilled waters, except that less water is to be added. Seeds and woody substances must be previously bruised or rasped. The oil distils over with the water, and, as it is lighter or heavier, floats on the surface or sinks to the bottom, and is afterwards separated. It is necessary to observe, in preparing these oils, and also the distilled waters, that the quality of the substances, their texture, the season of the year, and similar circumstances, must occasion so many differences, that no general rules, that are applicable to every case, can be laid down. Few of the volatile oils are prepared by the apothecary. The oils of anise, chamomile, juniper, origanum, rosemary, and pimento, are usually imported into this country; while those of lavender, peppermint, spearmint, and penny-royal, are annually prepared on a large scale.

As medical agents, volatile oils are stimulant and stomachic. They are chiefly employed to remove nausea and flatulence, to correct the griping qualities of some purgatives, and

the disagreeable taste of other remedies. They may be given triturated with water and mucilage; or dropped first on a lump of sugar, and through its medium diffused in water, forming a solution of what has been denominated "oleum saccharinum." The quantity of sugar must be more than ten times the weight of the oil; and when they are well triturated together the oil becomes thus completely soluble in water, and may be diluted to any extent. Some of the more stimulant of these oils are added to embrocations to be used as rubefacients in cases of numbness, pains, and paralytic affections of the joints. Thomson.

Oil of Wax. See *WAX*.

Oil frequently takes new names from the drugs mixed with it; as *oil of roses*, which is that mixed with roses; *oil of jessamy*, that perfumed with jessamin.

Oil of Wine. See *ETHER*.

Oil, Anointing with. See *UNCTION*.

Oil-Bag, a vessel in birds replete with an unctuous substance, secreted by one sometimes two glands, for the purpose, disposed among the feathers; which being pressed by the bill or head, emits its oily matter for dressing and pruning the feathers. See *Anatomy of BIRDS*.

Oil Beetle. See *Oil BEETLE*.

Oil-Bladders, in *Vegetable Physiology*. See *Secretions of VEGETABLES*.

Oil-Dregs. See *DREGS*.

Oil, Gilding in. See *GILDING*.

Oil, Painting in. See *PAINTING*.

Oil Mill, in *Mechanics*, is a machine used to express oil from linseed, rape-seed, and other oleaginous grain, but chiefly from the above-mentioned for the use of painters. Olive and other vegetable oils, the produce of the south of Europe, are also expressed by a machine, but it is not called a mill, being simply a strong screw-press, provided with a windlass or capstan, to give it a greater power; in short, it is the same machine as the *CYDER Press* (see that article). The olives are first pounded, or bruised, either in a large mortar, or by a running stone, in the same manner as the apples for making cyder. The pulp thus produced is put up in bags made of horse-hair, and a pile of these, being made up under the press, the screw is forced down by men working at a long lever, and the oil expressed: it runs very freely at first, and this, which is esteemed the best quality, is in some countries kept separate. When this pressure has continued an hour or two, the power of the capstan is applied. This produces a good quantity of oil of the second quality, which is sold at an inferior price; and in some provinces of Spain, where the olive is extensively cultivated, it is used to burn in their lamps.

The oil-mill we intend to describe in this article is for a different purpose; viz. the expressing of linseed and rape-seed oils. These grains are exceedingly hard and smooth on their surfaces, and the fragments of their shells, however broken, form little concavities which will retain the oil, unless a far greater pressure is applied than can be obtained by a screw-press; it is, therefore, done by a wedge-press. This consists of a strong block of wood, or a cast iron frame, in which a long mortise is made: in this a bag of bruised seed is placed at each end, and blocks being put in to fill up the mortise, a wooden wedge is introduced between the blocks, and driven in by repeated blows of a heavy stamper, which is raised up by the power of the mill, and let fall upon the wedge, till it has driven it down as far as it will go. This causes a most immense pressure upon the seed contained in the bags, and forces out the oil at every blow of the stamper: for it is a curious fact that the same

pressure, gradually produced, will not express any sensible quantity of oil; it must, therefore, be done by a sudden and violent accession of force; accordingly, at every stroke upon the wedge, the oil exudes in considerable quantity from the feed, until the whole is expressed, leaving a cake of feed as hard as a piece of board. These oil-cakes are very good food for cattle.

The machinery of an oil-mill is explained by the drawing in *Plate Oil-mill*, where *fig. 1.* is a plan, and *fig. 2.* an elevation, of a very good mill of this kind, which was erected after the designs of the late John Smeaton, esq. F.R.S.; whose proportions for the parts of mills have been scarcely improved since his time; though in the construction of the wheels, &c. cast iron has of late years been substituted for wood almost universally. *A*, in both figures, is the water-wheel actuating the whole mill; it is under-shot; that is, the water passes under it, and turns the wheel, by its momentum striking upon the floats. (See *WATER-WHEEL*.) It works very close, in a pit formed between the two walls *c*, *C*, the latter being the outside wall of the mill-house: it is framed on a strong octagonal shaft *B B*, turning on two gudgeons fixed in its ends: *D* is the pit-wheel, or great cog-wheel, fixed upon the main shaft, within the house: it has wooden teeth fixed in its rim, parallel to its axis, in the manner of a crown-wheel. There are 80 of these teeth, by which it turns a smaller wheel, *E*, of 37 teeth, fixed on an horizontal shaft, *F*, called the tumbling shaft, extending nearly across the house. It gives motion to the stampers, *V*, *W*, of the press, and also the rolling stones or runners, *I*, *K*, which bruise the feed. The latter is done by means of a wheel, *G*, with 35 teeth, fixed on the end of it, for the purpose of turning a large wheel, *H*, of 72 teeth, which is fixed upon a vertical shaft, *n*, which gives motion to the running stones, *I*, *K*. These are two circular stones, fitted upon an iron axle, the ends of which are shewn at *a a*. This axle passes through the vertical shaft *m*, and also through runners: thus they have two motions, a rotation round their own axis, by which they are carried round upon the nether or horizontal mill-stone, *L*, on which they roll. The centre-holes in these running mill-stones are made a little wide, and the hole in the shaft *m*, which carries the middle of the iron axis, is made oval up and down. This great freedom of motion is necessary for the runner mill-stones, because frequently more or less of the grain is below them at a time, and they must therefore be at liberty to get over it without straining the shaft.

The lower mill-stone, *L*, is supported on masonry, and surrounded by a border or ledge of wood *d d*, which prevents the feed being scattered: the two stones *I*, *K*, as the figure shews, are placed at different distances from the central axis *m*, so that they run in different paths, and thus bruise the feed more effectually than if they followed each other in the same circuit: *n*, *n*, are the ends of two wooden rails, projecting from the shaft *m*, and at their ends supporting two upright pieces of wood, which, at their inferior extremities, carry sweeps or rakes: these drag round upon the surface of the lower stone, and turn the feed about, to receive the greatest possible action from the stones *I*, *K*, rolling over it. There are two of these sweeps on the opposite sides of the stones, one called the outer rake, and the other the inner rake. The outer rake collects the grain under the runner from the surface of the border *d*. In this manner the grain is turned over and over, and crushed in every direction. The inner rake lays the grain in a slope or ridge, over which the runners pass, and crush it: then the second rake lifts it again into a ridge, to receive the action of the next stone, so that every side of the grain is presented to the runner mill-stone, and receives its action, while the rest of the lower stone is

swept by them so clean, that not a single grain is left on any part of it. The outer rake is also furnished with a rag of cloth, which rubs against the border of a hoop which surrounds the nether mill-stone, so as to drag out the few grains which might otherwise remain in the corners. There is also another sweep, making part of the inner rake, which is occasionally let down for sweeping off all the feed when it has been sufficiently bruised. The pressure and action of these rakes are adjusted by means of wooden springs, which cannot be easily and distinctly represented by any figure. The oblique position of the rakes (the outer point going foremost) causes them to shove the grain inwards, or towards the centre, and at the same time to turn it over somewhat in the same manner as the mould board of a plough shoves the earth to one side, and partly turns it over. Some mills have but one sweeper, and indeed there is great variety in the form and construction of this part of the machinery. The great pit, *D*, turns a small cog-wheel *e*, *fig. 1.* on whose spindle is fixed one of the two iron rollers *f*, *g*, which are used for bruising the feed, as in the first operation.

These rollers are made of cast iron, and truly turned in a lathe, their spindles turning in brass bushes, fixed in iron frames bolted down to the wood work. These frames have mortises in them, in which the bushes for the pivots of the roller, *g*, are placed, with liberty to slide in the mortises when they are pushed up by screws screwed through the ends of the iron frames. By these means the rollers can be set at any distance apart, according to the size of the feed which is to be crushed between them; *l*, *l*, are two small iron cog-wheels, of 15 teeth each, fitted on the ends of the pivots of the rollers; they make both rollers turn together with the same motion: the feed is put into a hopper, supported at some distance above the roller, and it runs out at an opening in the bottom into a trough called the shoe, which is continually shaken by means of a piece of wood nailed to it, and resting upon the cog-wheel *l*. By this means the shoe continually feeds the rollers with a small quantity of feed, without any danger of choking them up, and the seeds fall, from the end of the shoe, between the rollers, which, as they turn round, take the feed in between them, and bruise it. It is proper to have a piece of iron plate nailed to some part of the frame, and kept constantly pressing against the rollers, so as to scrape off the feed which may adhere to them. The feed, after having passed between the rollers, falls upon an inclined board, placed in the frame beneath them, and is thus shot down in a heap before the rollers, from whence it is conveyed by a labourer to the rolling stones.

The press comes next to be noticed, for we have hitherto only described the machinery for bruising the feed previous to expressing the oil from it.

The tumbling shaft, *F*, has two lifters, *M*, *N*, projecting from it, which as it turns round lifts up and lets fall the stampers, *V*, *W*, of the press. They rise and fall in a frame consisting of two thick pieces of wood *P*, *P*, firmly bolted together at the bottom by beams *T*, *T*, extended between them. The space between these beams is filled up by the bags of feed at *d*, *d*, *fig. 2.* the pressing wedge *b*, the discharging wedge *c*, and blocks of wood, to keep them at the proper distance apart.

The beams, *T*, *T*, have cross pieces upon them, between which the stampers, *V*, *W*, slide up and down: they are lifted up by the wipers or lifters *M*, *N*, fixed upon the shaft *F*: these take hold of tappets or chocks projecting from the stampers, and raising them to the proper height, let them fall on the wedges. When they are to be stopped, the workman pulls a rope, which raises a lever, and holds up the stamper too high to meet the lifter in its revolution. The

inverted wedge, *c*, is suspended by a rope from a wooden spring, which raises it up, as in the figure, when the other wedge is taken out for the purpose of putting a fresh charge of seed in the bags at *dd*. The opening of the prefs, or the space contained between the uprights, *P, P*, of the frame, and the two beams *T, T*, has a very strong cast iron frame within it, which resists the pressure to rend the prefs open. The upper edge of this frame is shewn by the dark line in *fig. 2*, and the internal parts are shewn by dotted lines.

The bags of seed, *d, d*, are included between two iron plates, united together at the bottom in the manner of book lids, and the bag is shut up between them: immediately beneath these are small holes in the bottom of the prefs, at which the oil oozes out into small pots *k, k*: the blocks which fill up the prefs rest upon the bottom of the prefs, to prevent them being carried down by the action of the wedges which slide against them, having thin pieces of wood between, to make them slide easily by each other: the pressing wedge, *b*, has its point downwards, and is driven by the stamper *V*: the discharging wedge *c* is inverted, its smallest end being upwards; and this, when struck by the stamper *W*, is forced down, and thus releases the prefs, when it would be exceedingly difficult to disengage it by any other means, the pressing wedge being driven in very fast by the repeated blows of the stamper *V*.

There is likewise a small apparatus in an oil-mill called the fire gear or chauffer pan, which we have omitted in our plate. It is intended to keep the bruised seed stirring whilst it is heated in a copper pan, previous to pressing, as this is found to increase the produce of oil. The chauffer pan consists of a small fire-place, situated in the corner of the mill-house, and heated by burning charcoal in it. The seed is contained in a circular copper pan, which is set over the fire, and the seed is prevented from burning to the bottom of the pan, by a cross piece of iron fixed to the lower end of a vertical spindle, which, as it turns round in the pan, stirs the seed. The sides of this cross are set inclined, so as to scrape the seed from the bottom of the pan, and throw it over the back of the stirrer. The spindle for the stirrer is put in motion by means of a train of small wheelwork, receiving motion from a rigger or pulley fixed upon the tumbling shaft *F*, by means of an endless chain or rope. In many of the most improved mills the chauffer pan is heated by steam instead of charcoal: in this case it has a false bottom on which the seed lays, and the steam from a boiler is admitted into the space beneath the bottom. This is found to give the proper heat with greater precision than can be done (except by experienced workmen) with the charcoal fire; for if the heat is too great it makes the oil rancid, and if it is too low the produce of oil will be diminished. In either case the pan must have a small opening on one side, and a sluice to shut it up and keep in the seed until it is properly heated. Immediately beneath the door are two hoppers, which lead the seed down at the side of the furnace, and conduct it into the flannel bags, which are hung at the lower extremity, or small openings of the hopper. When the seed is sufficiently heated, and the prefs is ready for it, the sluice is opened, and the stirrer throws the seed out into the hoppers and the bags. These are made of flannel cloth, which is found the best substance to resist the pressure and admit the oil through. The bags, before they are put into the prefs, are flattened by the hand, and wrapped up in a long slip of very thick leather, which encloses it, and prevents the bag being burst by the pressure.

Our readers will now comprehend the structure of the oil-mill; but as in all operations of this nature much management is requisite to carry them on to the best effect, we

shall briefly describe the process followed by our most careful manufacturers of oil.

Linseed and rape-seed are the produce of almost every county in England, and as the consumption of the oil for painting is not confined to particular places, the manufacture is carried on in every part of the kingdom. A great number of oil-mills are to be met with in Hull, and other parts of Yorkshire, where they have the advantages of falls of water. The seed is first bruised between the rollers, to crack every grain without separating their parts: this very much facilitates the operation of the grinding, for the grains are so hard and smooth, that they slip away from beneath the runner-stones, and it would require a long time to get all the grains crushed; but by the rollers every grain is broken, and then the runner-stones act with proper effect. The rollers require so much power, that in small mills they cannot drive the other machines at the same time; but this is no objection to them, because they act with such rapidity, as in a very short time to bruise seed enough for the whole day's work. The seed, after being crushed between the rollers, is spread by a shovel upon the nether mill-stone *L*, to be ground by the runners. That this may be more expeditiously done, one of the runners is set about two-thirds of its own thickness nearer the shaft than the other. Thus they have different circuits, and the grain, which is a little heaped towards the centre, is thus bruised by both. The inner rake gathers it up under the outer flanes into a ridge, over which the stone passes and flattens it: it is then gathered up again by the outer rake into a ridge under the inner stone. The outer rake consists of two parts; the outer part presses close on the wooden border *dd*, which surrounds the nether stone, and shoves the seed obliquely inwards, while the inner part of this rake gathers up what had spread towards the centre.

The outer rake has a joint near the middle of its length, by which the outer half of it can be raised from the nether stone, while the inner half continues pressing on it, and thus scrapes off the moist seed, which is like a paste. When the seed is sufficiently bruised, the miller lets down the outer end of the rake; this immediately gathers the whole charge, and shoves it obliquely outwards to the wooden rim, where it is at last brought to a part that is left unboarded, and it falls to the ground. In the Dutch mills it falls through troughs placed to receive it. These troughs have holes in the bottom, through which the oil drips all the time of the operation. This part of the oil is conveyed into a peculiar cistern, being considered as the purest of the whole, having been obtained without pressure, by the mere breaking of the hull of the seed.

The seed in this country is seldom so ripe as to yield any oil in this stage without pressure; but in some mills they take a quantity of their best seed from the stones, and putting it into bags give it a moderate pressure by a screw-press. The oil thus obtained is called cold drawn, and is sold at a higher price for the use of cabinet makers, who rub their ornamental wood work with it to give a polish: in other work, the cold drawn oil is nothing more than the first obtained by the prefs, but without heating the seed.

In some of the Dutch mills, a much greater quantity of oil is obtained in the grinding, without pressure, by having the bed of masonry, which supports the lower mill-stone, formed into a little furnace and gently heated. But the utmost care is necessary to prevent the heat from becoming considerable. This enabling the oil to dissolve more of the fermentable substance of the seed, exposes the oil to the risk of growing soon very rancid, and in general it is thought

a hazardous practice, and the oil does not bring so high a price.

When the seed is very dry, a little water is thrown in among it whilst grinding, which is found to facilitate the process. In about twenty minutes a charge of seed will be sufficiently ground, and is then carried to the chauffer pan, where it is heated previous to being pressed. Here the stirrer keeps it from burning to the bottom of the pan: while this is doing the wedges of the pres are taken out, both the stampers are hauled up, and the iron lids at *dd*, which are to include the bags of seed, are opened out ready to receive them. When the seed is sufficiently heated the sluice is opened, and the stirrer throws it out into the bags, the workman flattens them, wraps them in the leather, and puts them into their places. The wedge, *b*, is now introduced, and the stamper, *V*, disengaged to drive it down. After a few blows the oil begins to run, and this continues till the wedge gets so fast, that the stamper will rebound up from it two or three times: it is then judged that it can be driven no farther. The stamper, *V*, is now hauled up, and the other let loose. This at one or two blows drives down the wedge *W*, and relieves the pressure, after which the wedge and the bags may be taken out to put in a fresh charge. The contents of the bag are compressed into a dense cake, from which the bag is stripped off, and the cakes are ground up, and subjected to a second pressure. They are broken into pieces by the shovel, and thrown under the runners, where the cake is again broken down, and the parenchyma of the seed reduced to a fine meal. Thus free cress is allowed to the oil

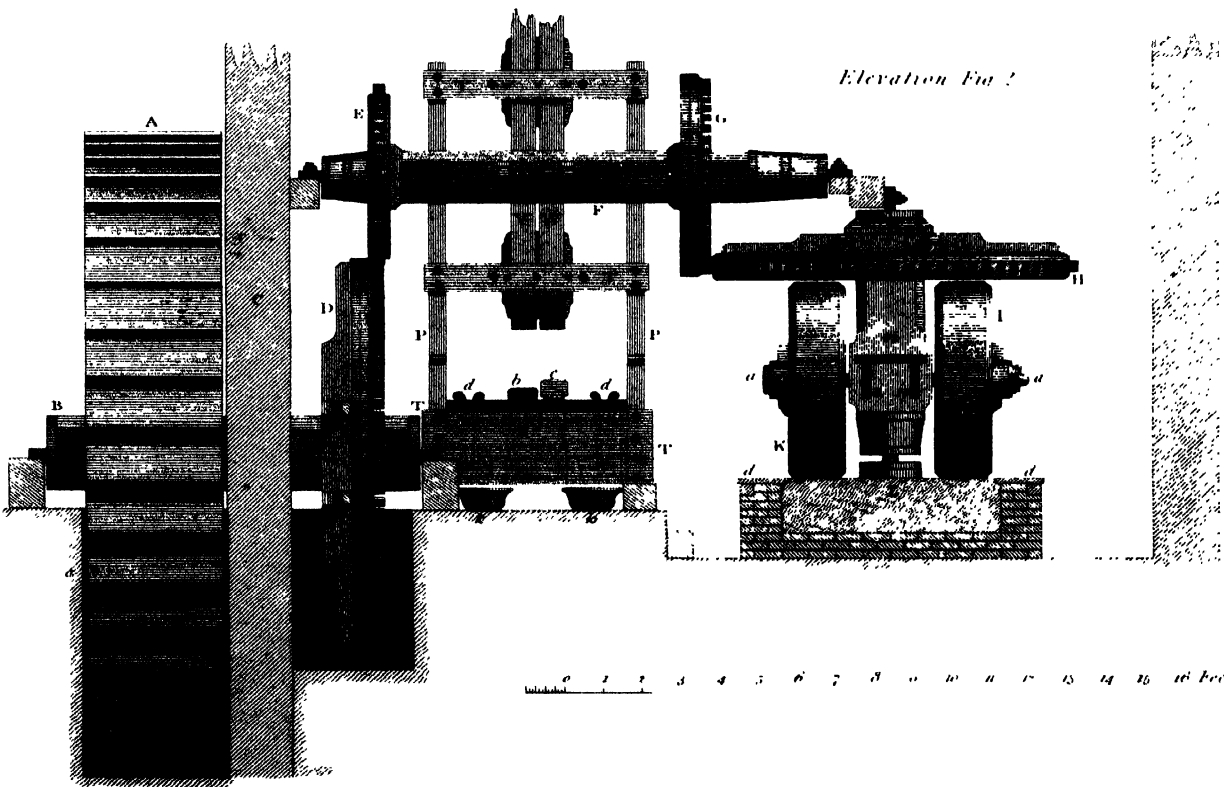
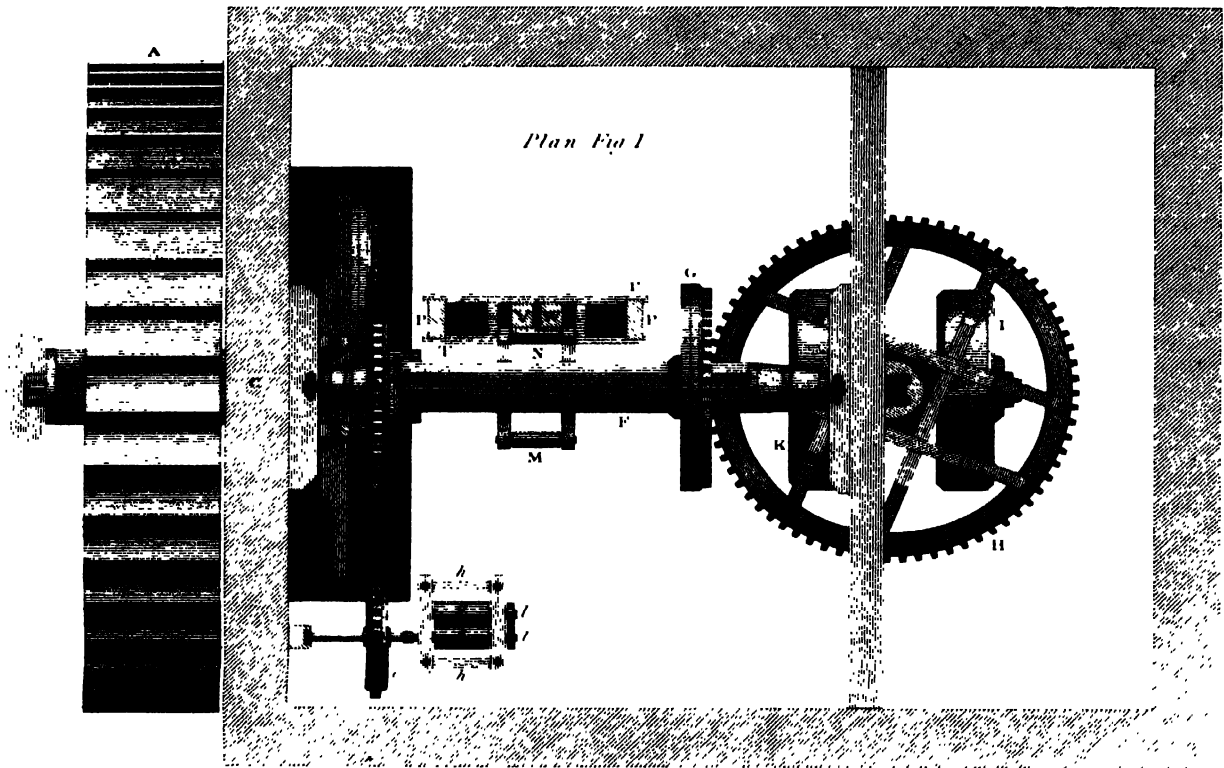
from every vesicle in which it is contained. But it is now rendered much more clammy by the forcible mixture of the mucilage, and even of the finer parts of the meal. When sufficiently ground the workman conveys the paste to the chauffer pan, where it is heated rather more than for the first time, and the second pressure is conducted in the same manner as the first. The produce of oil from the second operation is very uncertain; as it depends upon a number of circumstances. It will sometimes exceed the quantity of the first time, and at other times it will not be half as much. The bags for the second pressure are filled with twice as much seed as the first time, and the cake will be more than twice as thick. The linseed cakes are sold at a high price for cattle, but the rape-seed cakes are ground to a coarse powder, and in that state sold for manure.

The mill shewn in our plate is on a small scale, but many mills have from 10 to 15 presses in use. A press will generally press seven cwt. of seed *per* day the first time, but only two, or two and a half cwt. for the second time, because it requires as much more time for the last operation.

Respecting the produce of oil from linseed, we have found from an average of four months work of an oil-mill in Yorkshire, that 280 quarters of linseed, generally weighing 30 stone (of 14lbs. each) *per* quarter, produced 5616 gallons of oil, which is at the rate of $20\frac{3}{4}$ gallons *per* quarter. The greatest produce in the period from which this average was obtained, was 409 gallons from 20 quarters, or $20\frac{1}{2}$ gallons *per* quarter. The least produce was $19\frac{1}{4}$ gallons *per* quarter.

OIL MILL.

BY M^r SMEATON.



0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 Feet.

Ores

ORES, in *Mineralogy* and *Metallurgy*, signify those mineral substances found in the earth, from which metals are procured. The ores of most of the metals consist of the metal combined with some other substance, and the process by which the metal is separated from the combined matter, is termed the reduction of the ore. We shall not here enumerate the ores of the different metals, as they are amply treated of under the respective metals.

Affay and Analysis.—This branch of operative chemistry is divided into two parts, the one called the humid, and the other the dry analysis. By the first of these, the substance is dissolved in acids or alkalies, and the different constituents separated by different re-agents. The dry process consists in first exposing the ore to a red heat, for the purpose of separating its volatile parts. The remainder is then treated with certain fluxes and inflammable matter, to separate the metal which is found in a rounded form, at the bottom of the crucible, and hence is called a button.

A little reflection will make it clear, that the humid analysis should always precede that of the dry. In order to know the nature of the particular flux to be employed after its ore has been roasted and its volatile products ascertained, it may be subjected to the action of some acid, and first the muriatic. If this has no action upon it, try the nitric; should this acid not dissolve the whole, try the nitromuriatic, which may consist of equal parts of the two acids. If the whole is not dissolved by this, it may be presumed that the ore contains flint, or some salt not decomposable by the above acids. Under either of these circumstances it is proper to fuse the ore with pure potash, in a silver crucible. The fused mass will be of a dark green if iron be present, of a grass green if the ore contain copper, blue with cobalt, yellow with lead, and purple with manganese. This mass being boiled for some time with distilled water, till all the soluble matter is taken up, must now be treated with nitric acid. It is probable that all, except the silica, will be dissolved in the acid. From this acid solution, with the different lifts, it must be ascertained what are the constituents of the ore, and afterwards the different substances must be separated with a view to determine their proportions. See under the different metals *Affay and Analysis*.

When the nature and proportions of the different substances combined with the metal constituting the ore are made out, the next thing is to expose it in a crucible, with such substances as will combine with the matter to be separated, the compounds either becoming fusible or being separated in the form of gas. For instance, in the smelting of iron ores of the argillaceous kind, lime is used in order to form a fusible compound with the alumine, and charcoal or coak in order to form carbonic acid with the oxygen of the oxyd of iron. If the ore contain silica, potash or soda should be used in order to form glass, which is greatly more fusible than the earth would have been with the metallic oxyd alone. Borax is frequently employed as a flux from its great facility of combining with the silica and other earths. See STONES, *Analysis of*.

ORES, *Dressing, or Washing of*, is the preparing them as they come rough from the mine, for the working by fire. This is done several ways in different countries, and in respect

to the different ores of the metals. In Devonshire we have a very easy method, which is so expeditious, and so good for all the purposes, that it is worthy of imitation in other places. After the ore is dug, it is tossed up by hand from shamble to shamble by the shovel-men in the mine, and drawn up in buckets by a winch at the top of the shaft. As soon as the whole quantity for one dressing is brought up, the large stones are broken, and the whole is then carried to the mills, where one horse turns a wheel that moves the machines for powdering a great quantity of it: these are called the stamping or knocking mills. The ore is unloaded at the head of the pass or entrance into these mills: this pass is made of two or three bottom-boards and two side-boards, in form of a hollow trough, and stands in a slanting direction. The ore by its own weight is carried down this trough, and lodges itself in the coffer. The coffer is a long square box, made of the firmest timber, and of three feet long, and a foot

and half broad. The ore is not suffered to fall into this all at once, but is stopped over the mouth of the trough by a cross board, where a cock turns in a quantity of water at the same time, which washes down just as much of the ore with it into the trough, as there ought to be. In this coffer there are three lifters placed between two strong board-leaves, having two braces or thwart-pieces on each side to keep them steady, as a frame with stamp-heads. These heads are of iron, and weigh about thirty or forty pounds a-piece, and serve to the breaking of the lumps of ore in the coffer.

The lifters are about eight feet long, and half a foot square. They are always made of heart of oak, and have as many in-timbers or guiders between them: they are lifted up in order, by a double number of tappets, which are fastened to as many arms passing diametrically through the great beam, which is either turned by the wheel and horse, or, where there is a convenience of water, by an overshot water-wheel on two boulders. The tappets exactly but easily meet with the tongues, which are so placed in the lifters, as that they easily slide from each other, and suffer the lifters to fall with great force on the ore in the trough. The frequent pounding of these soon reduces the large masses into a sort of sand, which is washed out of the trough by the continual current of the water from the cock through a brass-grate, which is placed at one end of the coffer between two iron bars. This operation is called by the miners *bricking*, or brick-working the ore. See BUDDLE.

The powdered ore is conveyed out of the trough into the *launder*, which is a trench cut in the floor of eight feet long, and ten feet over. This is stopped at the lower end with turf, so that the water is all suffered to pass away, and the powder of the ore is stopped. Thus the launder by degrees fills up with the dressed ore, and this is removed out with shovels, as occasion requires. The launder is divided into three parts, the forehead, the middle, and the tail: that ore which lies in the forehead, that is, within a foot and a half of the grate, is always the richest and best, and is laid up in a heap by itself; the middle and tail afford a poorer one, and these are sometimes laid up in separate heaps; sometimes thrown in one heap together.

Paper

PAPER, a thin flexible leaf, usually white, artificially prepared of some vegetable substance, chiefly to write upon with ink

The word is formed from the Greek *παπυρος*, *papyrus*, the name of an Egyptian plant, called also *βιβλος*, *biblus*, on which the ancients used to write.

Various are the materials on which mankind, in different ages and countries, have contrived to write their sentiments; as on stones, bricks, the leaves of herbs and trees, and their rinds or barks; also on tables of wood, wax, and ivory; to which may be added plates of lead, linen rolls, &c. At length the Egyptian papyrus was invented; then parchment, then cotton paper; and, lastly, the common, or linen paper. Vide Maffei Ist. Dipl. lib. ii. § 3. 10. Bibl. Ital. tom. ii. p. 242. Leo Allat. Antiq. Hetrusc. p. 127, 129. Hug. de Scrib. Origin. Alex. ab Alexand. lib. ii. cap. 30. Barthol. diss. 4. de Libr. Legend. p. 90, seq.

In some places and ages they have even written on the skins of fishes; in others on the intestines of serpents; and in others on the backs of tortoises. (Mabill. de Re Dipl. lib. i. cap. 8. Fabric. Biblioth. Nat. cap. 21, &c.) There are few sorts of plants but have at some time been used for paper and books: and hence the several terms, *biblos*, *codex*, *liber*, *folium*, *tabula*, *tillura*, *philura*, *scheda*, &c. which express the several parts on which they were written: and though in Europe all these disappeared upon their introduction of the papyrus and parchment, yet in some other countries the use of divers of them obtains to this day. In Ceylon, for instance, they write on the leaves of the talipot. And the Bramin MSS. in the Tulinga language, sent to Oxford from Fort St. George, are written on leaves of the ampana,

or palma Malabarica: Hermannus gives an account of a monstrous palm-tree called *codda pana*, or *palma montana Malabarica*, which, about the thirty-fifth year of its age, rises to be sixty or seventy feet high, with plicated leaves nearly round, twenty feet broad; with which they commonly cover their houses; and on which they also write; part of one leaf sufficing to make a moderate book. They write between the folds, making the characters through the outer cuticle. Knox. Hist. Ceyl. lib. iii. Le Clerc. Bibl. Univ. tom. xxiii. p. 242. Phil. Trans. N° 246. p. 422, seq. Vide Hort. Ind. Malab. p. 3. Phil. Trans. N° 145. p. 108.

In the Maldivé islands, the natives are said to write on the leaves of a tree called *macaraquean*, which are a fathom and a half long, and about a foot broad. And in divers parts of the East Indies, the leaves of the musa arbor, or plantain-tree, dried in the sun, served for the same use, till of late that the French have taught them the use of European paper. Ray, in fine, enumerates divers kinds of Indian and American trees which bear leaves proper to be used as paper; particularly one called *xagua*, which has something in it extraordinary; its leaves are so large, and of so close a texture, that they cover a man from top to toe, and shelter him from the rain, and other inclemencies of the weather, like a cloak: and from the innermost substance of these leaves, a paper is taken; being a white and fine membrane like the skin of an egg, as large as a skin of our vellum or parchment, and nothing inferior for beauty and goodness to the best of our papers. Vide Savar. D. de Comm. tom. ii. p. 967. Vide Ray Hist. Plantar. tom. ii. lib. 32. Nouv. Rep. Let. tom. xii. p. 361.

Paper is chiefly made among us of linen, or hempen rags,

beaten to a pulp in water, and moulded into square sheets, of the thickness required. But it may also be made of nettles, hay, turnips, parsnips, colewort-leaves, asbestus, or any thing that is fibrous; nay, it may be made of white woollen rags: though this would not serve for writing, because of the hairiness. The Chinese paper is so fine, that many of the Europeans have thought it was made of silk; not considering, says Du Halde, that silk cannot be beat into such a paste, as is necessary to make paper: but it is to be observed, that the same author afterwards speaks of a paper, or parchment, made of the balls of silk worms; and the like, we are assured by others is done at Cathay. Hought. Collect. N^o 360. tom. ii. p. 418, seq. Description of China, p. 360. seq. Vide Busbeq. Legat. Turc. Epist. iv. p. 329.

PAPER, with regard to the manner of making it, and the materials employed therein, is reducible to divers kinds: as the *Egyptian*, *European*, and *Chinese paper*: we also find mention of *cotton paper*, *bark-paper*, and *asbestine* or *incombustible paper*.

PAPER, *Egyptian*, is that which was principally used among the ancients: it was made of a rush called papyrus, or biblus, growing chiefly in Egypt, about the banks of the Nile: though it was also found in India; and Guilandinus assures us, he saw in Chaldaea, at the confluence of the Tigris and Euphrates, large fens, in which, with his own hands he plucked a papyrus differing in nothing from that of the Nile. Strabo likewise speaks of a sort of papyrus growing in Italy; but we do not find this was ever used for making paper.

The description given by Pliny of the papyrus, or paper-reed, is somewhat obscure. Its root, according to him, is of the thickness of a man's arm, and ten cubits long; from this arise a great number of triangular stalks six or seven cubits high, each thick enough to be easily spanned; its leaves are long like those of the bull-rush; its flowers flameous, ranged in clusters at the extremities of the stalks; its roots woody and knotty like those of rushes, and its taste and smell near akin to those of the cyperus, under which genus Linnæus has classed the papyrus. (See CYPERUS.) Vide Plin. Hist. Nat. lib. xiii. cap. 11. Vide Theophr. Hist. Plant. lib. iv. cap. 9. and Delecamp, who gives us a figure of it, Hist. lib. xviii. p. 1883. See also Bauhin. lib. xviii. cap. 186, who, with Gesner, makes it a species of Cyperus. Grew Mus. Reg. Societ. p. 2. sect. 2. p. 225, seq. Maffei Istor. Diplom. Bibl. Ital. tom. ii. p. 246.

Besides paper, they made sails, ropes, and other naval rigging; as also mats, blankets, clothes, and even ships, of the stalk of the papyrus. Moses, we are told, when a child, was exposed on the banks of the Nile, εν βιβλη παπυρου, i. e. in a basket of papyrus. The Egyptian priests wore shoes of papyrus.

Guilandinus, a Prussian physician before mentioned, has a celebrated work expressly on the ancient papyrus, by way of commentary on three chapters of Pliny, in which is amply, and with great learning, explained all that relates to this subject; yet Scaliger has written a severe critique on it, in which some inaccuracies of Guilandinus are pointed out; but this has not hindered Kirchmayer from adopting almost Guilandinus's whole book in his dissertation on the papyrus. Add, that the most ingenious and learned count Scipio Maffei has lately vindicated Guilandinus against the exceptions of Scaliger, as well as of Vossius and Hardouin. (Vide Istor. Diplom. lib. ii. Bibl. Ital. tom. ii. p. 248. Melch. Guilandini Papyrus, h. e. Commentarius in tria C. Plinii Majoris de Papyro capita, sc. lib. xiii. cap. 11, 12, 13, first published at Venice in 1572, and afterwards

at Amberg, in 1613, by Salmuth.) It seems, Guilandinus intended a commentary on the whole of Pliny's Natural History; but this small part, not exceeding a moderate page, taking him up full six months, it is no wonder he was discouraged from proceeding with the rest. In these three chapters he has restored about twenty passages in the text of Pliny, not merely from his own conjecture, or the help of MSS. but from the nature of the things described, and the testimonies of authors of the first rank: besides that, he had been upon the spot, where formerly the papyrus was manufactured, and had carefully examined all the ancient Greek and Latin authors who speak of it.

Joh. Just. Scaligeri Animadversiones in Melchioris Guilandini Commentarium in tria C. Plinii capita, lib. xiii. Historiæ Mundi five Naturalis, quibus agit de Papyro, first published in the Lectiones Bibliothecarum Memorabiles, of Rudolphus Capellus, at Hamburg, in 1682, where he follows Guilandinus step by step, finds as many faults in him as his father had done in Cardan, and sets him altogether as coarsely; every where pointing out his literary mistakes, and labouring to shew, that instead of restoring Pliny, he has often mistaken and corrupted him. M. Seb. Kirchmaieri Offenheimeris Franci Dissertatio Philologica de Papyro veterum, Wittebergæ 1666, 4to.

He had done better service, if, besides Guilandinus, he had consulted others, and particularly Scaliger. But as he chose to follow one rather than many, and that too as the blind follow their guides, his fate has been much the same.

The origin of the art of making paper of the papyrus is very obscure; no doubt it was first discovered in Egypt. Isidore fixes it more particularly to the city Memphis, Orig. lib. vi. cap. 10. in which he seems to be countenanced by Lucan, where he says,

"Nondum fluminea Memphis contexere biblos
Noverat——"

Pharfal. lib. iii. v. 222

The era of this invention is warmly disputed: Varro, the most learned of the Romans, fixed it to the time of Alexander the Great, after the building of the city of Alexandria by that conqueror; but several objections, of no small weight, are brought against this decision. Pliny recites a passage out of a very ancient annalist, one Cassius Hemina, wherein mention is made of paper books found in Numa's tomb, five hundred and thirty-five years after his death, which had been buried with him: now Numa was prior to Alexander by above three hundred years. Guilandinus, in effect, maintains, with great erudition, that the name and use of the papyrus were known to the Greeks long before Alexander conquered Egypt; and that the words βιβλος, and βιβλι, occur in their received signification in authors prior to, or at least older than, Alexander: particularly Anacreon, Alcæus, Plato the comedian, Aristomenes, Cartinus, Antiplanes, Plato the philosopher, Æschylus, and Aristotle. And whereas some speak of a kind of unknown pseudo-biblos, in use before the discovery of the true sort, he argues, on the contrary, that the biblos mentioned by those authors, prior to the conquest of Alexander, appears from Herodotus, Theophrastus, and others, to be the very same plant with the biblus, or papyrus, of which paper was afterwards made: even Homer and Hesiod, the most ancient Greek poets, and who by Herodotus's testimony lived about four hundred years before himself, appear to have been no strangers to the papyrus, since they both make express mention of it. Vide Plin. lib. xiii. cap. 13. Guiland. Papyr. Membr. 2. Reim. Idea Syft. Antiq. Liter. p. 285, seq. Kirchman Diss. de Papyr. art. 11. sect. 2.

To this it may be answered, that supposing the plant papyrus known in Greece long before Alexander's conquest of Egypt; it no more follows, that they had then the use of paper; than it follows, that men had wine immediately on the discovery of the vine.

In reality, Guilandinus produces testimonies, from Anacreon and Alcæus, in which the papyrus is employed for binding, and not for paper; add, that he ill translates *το φρεαλυχρον*, *ellyphnium*; since *λυχρον* here is the torch itself. Nor does the poet say it was made of papyrus, but tied up with it. Vide Scalig. lib. cit. Reimm. ubi supra, p. 305. seq.

Some have even doubted whether the art of manufacturing the papyrus was so ancient as Alexander's time; chiefly on this ground, that, for two hundred years after Alexander, men wrote on skins, and on the barks of trees: but this is nowise conclusive. The scarcity of the new manufacture may account for it: for some ages afterwards, even as low as Tiberius, we read of such a scarcity of paper, that its use, even in contracts, was dispensed with by a decree of the senate, and the opinion of the judges. The same consideration may be carried farther: paper might have been known in Egypt, Judæa, Syria, and Asia on this side Taurus, long before the birth of Alexander, though not in common use; but it might be later before the Europeans received it; and probably it was by means of Alexander's conquest that it first became publicly known there.

When the manufacture of the Egyptian paper ceased, is another question; for, at present, the *papyrotechnia Ægyptiaca* may be reckoned among those arts that are lost. Eustathius, the learned commentator on Homer, testifies, that even in his time, viz. in 1170, it was disused: Mabillon, indeed, maintains, that it continued till the eleventh century after Christ; and cites one Fridegod, a monkish poet of the tenth century, as speaking of it as subsisting in the age before his, that is in the ninth; and that it continued longer, the same Mabillon endeavours to evince, from several papal bulls wrote on it as low as the eleventh century. Vide Eustath. ad Homer. Odyss. φ. Voss. de Art. Gram. lib. i. c. 37. Vide Mabill. De Re Diplom. lib. i. cap. viii. sect. 6. seq. Reim. Idea Syst. Antiqu. Liter. p. 311.

Maffei, on the other hand, maintains, with more probability, that the papyrus was generally disused before the fifth century; for that we find no authentic records, written on it, dated since that time; those bulls of popes, cited by Mabillon, appearing rather to be written on cotton paper. But this, we may observe, relates only to the general and legal use of the papyrus. For that it should have continued to be made by particular persons several hundred years after it first began to give way, is not to be wondered at. Vide Maffei Ist. Diplom. loc. cit. Bibl. Ital. tom. ii. p. 251.

In reality, a more commodious sort of paper, made of cotton, having been invented some ages before in the East, and coming to be introduced into Europe, seems to have brought the papyrus into disuse. To which the continual wars with the Saracens, by which the traffic to Alexandria was rendered precarious, might possibly not a little contribute.

Yet several books, written on leaves of the papyrus, have even continued to our days: Mabillon says, he had one of them; and adds, that there was another in the Petavian library, being a volume in small folio, containing several sermons of St. Augustine; he also mentions a third, containing that father's epistles, formerly belonging to the church of Narbonne, and afterwards in the custody of madame De Phirmacon; besides the homilies of Avitus, bishop of

Vienne, and divers diplomas or charters, all written on the papyrus, which appear not to be less than eleven hundred years old. But the decisions of this learned father concerning MSS., notwithstanding all his diplomatic skill so highly boasted of, are not always infallible; witness his taking the MS. of St. Mark's Gospel, at Venice, to be written on the Egyptian papyrus; and that of Josephus, at Milan, not to be so. Maffei shews, on the contrary, that the former is cotton paper; and that the latter appears, at first sight, to be Egyptian; not but the Venetian MS. is very old; but it has been so much used, that its leaves are, as it were, transformed into the original paste from whence they are made. Vide Mabill. Suppl. ad Libr. de Re Diplom. Journ. des Scav. tom. xxxii. p. ii. p. 992. Maffei, lib. cit. Bibl. tom. ii. p. 252. And Montfaucon. Paleog. Græc. p. 14.

PAPER, *Manner of making the Egyptian.* They began with lopping off the two extremes of the papyrus, viz. the head and root, as of no use in this manufacture; the remaining stem they slit lengthwise into two equal parts, and from each of these they stripped the thin scaly coats or pellicles, of which it was composed, with the point of a pen-knife. The innermost of those pellicles were looked on as the best, and those nearest the rind or bark the worst; they were kept apart accordingly, and constituted different sorts of paper.

These pellicles are called, in Pliny, by twelve different names; viz. *philura*, *ramentum*, *scheda*, *cutis*, *plagula*, *corium*, *tenia*, *subtegmen*, *statumen*, *pagina*, *tabula*, and *papyrus*.

The generality of critics, in lieu of a pen-knife, employ a needle to separate the pellicles; in which they are warranted by the common text of Pliny, "Præparantur ex eo chartæ, diviso acu in præstenuas, sed quam latissimas philuras." But Guilandinus makes a correction here: he had found, by experiment, that the pellicles of papyrus cannot be separated by a needle; but that a very sharp knife is required; for which reason, instead of *diviso acu*, he reads *diviso scapo*. In which he is followed by Maffei, though Hardouin, Vossius, Pitiscus, and others, retain the ancient reading. Vide Guiland. Papyr. Membr. 10. sect. 3. and 5. Maffei Ist. Diplom. ap. Bibl. Ital. tom. ii. p. 247, seq. Voss. De Art. Grammat. lib. i. cap. 37. Pitisc. L. Ant. tom. i. p. 413. voc. Charta. Hardou. ad Plin. lib. xiii. cap. 12.

As the pellicles were taken off, they extended them on a table; then two or more of them were laid over each other transversely, so as that their fibres made right angles: in this state they were glued together by the muddy waters of the Nile. These, being afterwards pressed to get out the water, then dried and lastly flattened and smoothed by beating them with a mallet, constituted paper: which they sometimes polished farther by rubbing it with an hemisphere of glass or the like.

In other countries where the waters of the Nile were not to be had, the pellicles were fastened together with a paste made of the finest wheat-flour, mixed with hot water, and a sprinkling of vinegar.

The ingenious and learned count de Caylus, in his account of the papyrus, informs us, that the intermediate part of the stalk was cut and separated into different laminæ, which were set apart, and dried in the sun for the manufacture. These laminæ were joined together horizontally or transversely, in sheets or leaves, upon a smooth board: then moistened with water, which dissolved a kind of viscous glue in the pores of the plant, serving to cement and render the whole uniform. The sheet, being thus formed, was put into a press, and afterwards dried for use. Such,

he says, was the process of making paper in Egypt; but as the sheets were coarse, brown, unequal, and imperfect, the Romans invented methods to bring the fabric to perfection. They contrived a glue or gum, by means of which they could occasionally enlarge the size and volume. They bleached it to a surprising degree of whiteness; they beat it with hammers, so as to render it more thin and less porous; they smoothed and polished it with ivory; and by a sort of calender gave it a shining gloss, like that of the Chinese paper. According to the different degrees of delicacy, whiteness, and size, it acquired different appellations either from the names of particular manufactures, from the great personages who used it, or from the particular uses to which it was applied; such as the Fannian, the Livian, the Claudian, the Imperial, the Hieratic and the Amphitheatric.

There were paper manufactures in divers cities of Egypt; but the greatest and most celebrated was that at Alexandria, where, according to Varro's account, paper was first made. It is certain at least it was from hence that Greece and Italy was furnished, on account of the convenient situation of that port; and it is more than probable it was this that gave the Romans occasion to conclude the art had been invented there. It was not till late, when Egypt was reduced into a Roman province, that they had much intercourse, or even knowledge of the inland cities of Egypt, where paper was also made. The trade and consumption of this commodity were in reality incredible. Vopiscus relates, that the tyrant Firmus, who rebelled in Egypt, publicly declared he would maintain an army only with paper and glue, "papyro & glutine." This, Calaubon understands as spoken of the produce and revenue of paper; though Salmassius takes it to be meant of the papyrus itself, which could supply most of the necessities of life. Vide Montfauc. Palæogr. Græc. lib. i. cap. 2. p. 14.

We find divers species of Egyptian paper mentioned in ancient writers: some denominated from the places where they were manufactured; as 1. The *Amphitheatrica*, supposed to have been made in some building belonging to an amphitheatre at Alexandria; though Guilandinus, with more probability, reads it *Arthribitica*, from Arthribus, a city in the middle of the Delta, which was the place of its manufacture. What countenances this correction, is, that we find mention of this paper before there was so much as an amphitheatre at Rome, much less at Alexandria. 2. *Saitica*, made in the city Sais. 3. *Tanotica*, or, according to others, *Taitica*, whose place authors are not agreed on. There were also other sorts denominated from the makers; as 1. The *Fanniana*, from the grammarian Rhem. Fannius Palæmon, who kept a paper work. This kind was small, but finer than the Amphitheatrical paper; being first wrought at Alexandria, and afterwards finished at Rome. 2. *Claudia*, first made by order of the emperor Claudius. This was reputed the best of all, in that, besides the two pellicles, in common with the rest, it had a third. Others were denominated from the uses they were intended for; as, 1. *Hieratica*, the first or oldest sort, which was appropriated to religious uses; this was afterwards denominated *Augusta* and *Liviana*, in compliment to the emperor of that name, and his wife; who, according to some, improved and made it whiter than before. 2. *Emporetica*, or *Emporica*, a small and coarse sort, serving for shopkeepers' uses, to tie up goods, &c. The qualities for which the ancient papers were prized, were their thinness, closeness, whiteness, and smoothness; though their breadth also considerably enhanced their value. That sort called *charta Claudia* was thirteen inches wide; the *Hieratica*, eleven; the *Fanniana*,

ten; and the *Amphitheatrica*, nine; as to the *Saitica*, it exceeded not the diameter of the mallet it was beaten with.

See farther concerning the ancient paper, in Nigrifoli Diff. de Charta, ejusque Ufu apud Antiquos. Ext. in Galer. de Minerv. tom. iii. p. 249, seq. Other authors are enumerated in Fabric. Bibl. Antiq. cap. xxi. sect. 9. p. 609. Pitisc. L. Ant. loc. cit.

PAPER, *Bark*, if it may be so called, was only the *liber*, or inner whitish rind enclosed between the outer bark and the wood of divers trees, as the maple, plane, beech, and elm, but especially the *tilia*, *φίλυρα*, or *linden-tree*, which was that mostly used for this purpose. On this, stripped off, flattened, and dried, the ancients wrote books; several of which are said to be still extant. Vide Plin. Hist. Nat. lib. xiii. cap. 11. Hardou. Not. ad eund. Suid. Lex. in voc. *φίλυρα*. Ibid. Orig. lib. vi. cap. 13. Alexand. ab. Alexand. lib. ii. cap. 30. Salmuth. ad Pancirol. lib. ii. tit. 13. p. 252, seq.

Mabillon and Montfaucon speak frequently of manuscripts and diplomas on bark, and are very express in distinguishing between the papyrus used by the Egyptians, and the liber or bark in use in other countries. The two are alleged to differ in this, that the bark paper was thicker and more brittle than the papyrus, as well as more apt to cleave or shiver, by which the writing was sometimes lost; as is the case in a bark manuscript in the abbey of St. Germain's, where the bottom of the paper remains, but the outer surface, on which the letters had been drawn, is in many places peeled off. Vide Montfauc. Palæogr. Gr. lib. i. cap. 2. p. 15. Mabill. de Re Diplom. lib. i. cap. 8. Reimm. Idea Syst. Antiq. Liter. p. 311.

But Maffei, it must not be forgot, combats the whole system of bark manuscripts and charters as a popular error; and maintains, that the ancients never wrote diplomas on bark; that the distinction between the papers made of papyrus and of cortex, is without foundation; that the only use of the *tilia*, or *linden*, was for making thin boards or tablets for diptycha or pocket-books, wherein they wrote on both sides, as is done among us: an advantage which they could not have in the Egyptian paper, by reason of its thinness.

A late French writer on the rules of criticism wanders still farther out of the way, when he speaks of a sort of paper, in Egypt, made of the pith of the cyprus: he describes the manner of preparation, which was by reducing this pith to a pulp, and then spreading it out in leaves. Vide Hon. St. Marie Reflex. sur les Regl. de la Crit. tom. ii. diff. 77. This we suspect for a chimera hatched only in the critic's brain.

Not but there occur divers anomalous sorts of paper, which antiquaries are not a little puzzled what species to refer them to; such is that of two bulls in the archives of the church of Gironne, issued by the anti-popes Romanus and Formosus, between the years 891 and 895. They are two ells long and one broad; and consist of two leaves or pellicles glued together transversely, and are still legible in most places. The conjectures of the French literati, in regard to these, are numerous; the abbot Hiraut de Belmont has a discourse express on the occasion. Some will have them made of the leaves of the *alga*, or sea-wreck; others of the leaves of a rush, called *la boga*, growing in the marshes of Roussillon; others of papyrus; others of cotton; and others of bark. So little certainty does there really appear to be in these things, on which the critics nevertheless often lay a great stress. Vide Mem. de Trev. Sept. 1711. p. 1559, seq.

PAPER, *Cotton*, *charta bombycina*, *βουμβυκίνη* (thus called

from *βουβύζ*, a word which anciently signified *silk*, though in after-times *βουβύζ* and *βαμβύζ* came to denote *cotton*), is a sort of paper which has been in use upwards of seven hundred years ago, as is shewn by Montfaucon from several authorities; what is more, cotton paper appears to have been very common at the beginning of that time, and consequently must have been invented long before, probably about the close of the ninth, or the beginning of the tenth century.

In the French king's library are MSS. on this paper, which, by the character, and other circumstances, appear to be of the tenth century. Be this as it will, from the twelfth century, cotton MSS. were more frequent than parchment ones. Vide Montfaucon. Palæogr. Græc. lib. i. cap. 2. p. 17, seq. item, lib. iv. cap. 6. p. 209. Maffei, lib. cit. Bibl. Ital. tom. ii. p. 252.

PAPER, *Incombustible*, is made of the lapis asbestos, or linum vivum, which will bear burning without being injured.

Dr. Bruckman, professor at Brunswick, has published a natural history of the asbestine, or incombustible paper; and, what is most remarkable, has printed four copies of his book on this paper: they are deposited in the library of Wolfenbützel. Vide Bibl. Germ. tom. xiv. p. 190.

The manner of making this extraordinary paper is described by Mr. Lloyd, from an essay made by himself. He pounded a quantity of the asbestos in a stone mortar, till it became a downy substance; then sifted it in a fine sieve, and by this means purged it indifferently well from its terrene parts; because the earth or stones he could not pick out of it before, or at the pounding, being reduced to a powder, came through the sieve, the linum remaining. This done, he brought it to the paper-mill; and putting it in water, in a vessel just big enough to make a sheet with such a quantity, he stirred it pretty much, and desired the workmen to proceed with it in the usual method, with their writing-paper mould; only to stir it about always before they put their mould in; considering it as a far more ponderous substance than what they used; and that consequently, if not immediately taken up after it was agitated, it would subside.

The paper made of it proved but coarse, and was very apt to tear; but this being the first trial, there is reason to believe it might be much improved; nor did the workmen doubt, but in case it were pounded in one of their mortars, for twenty hours space, it would make good writing-paper. Vide Phil. Trans. N° 166. p. 824. See ASBESTOS.

PAPER, *Linen or European*, is chiefly made of linen rags beaten to a pulp with great hammers, and the foil carried off by a continual supply of fresh water, conveyed among the pulp in little troughs, till it be rendered perfectly white.

Besides the chief use of this paper, which is for writing and printing, there is a great consumption of it in packing up goods, and on other occasions.

The manufacture of paper has got footing in most countries; though France, Holland, and Genoa, are the places where it has succeeded best. In the general it depends much on the quality of the linen worn in the country where it is made; where that is coarse and brown, &c. the rags, and consequently the paper made of them, must be too. Hence the whiteness of the Dutch and Flemish papers, beyond the Italian and French, and much more the German papers. The English manufacture was a long while in no great reputation; but it is every day improving; inasmuch that we now import little of the ordinary sorts, which were formerly all brought from abroad. Yet paper-mills are of some standing among us. We find one erected at Dartford

as early as the year 1588, which we believe was the first, and which is celebrated by a noted poet of that age, Tho. Churchyard, in a work in verse, intitled "A Description and Discourse of Paper, and the Benefits it brings; with the setting forth of a Paper-mill, built near Dartford, by a High-German, called Mr. Spilman, Jeweller to the Queen, Lond. 1588. 4to."

In reality, the deficiency of the English paper manufacture did not seem owing so much to the quality of our rags, as to the want of skill and attention in the makers; but the manufacture of paper has been very considerably encouraged in our country, and has already arrived to a great degree of perfection.

Anderfon, in his Hist. of Com. vol. ii. p. 197. says, that till about the year 1690, there was scarcely any other kind of paper made in England, but the coarse brown sort. But the war with France occasioning high duties on foreign paper, the French Protestant refugees settled in England chiefly, and also our own paper-makers now began to make white writing and printing paper, which, he adds, in length of time, has been brought to so great perfection, both for beauty and substance, that in our own time we import only certain kinds of Genoa and Dutch paper, which bears but a very small proportion to all the paper used in the British dominions. This has produced, it is said, a saving to Britain of 100,000*l.* which was paid annually to France for paper only.

Another writer says, that the English manufactures now provide above seven-eighths of the whole quantity of paper consumed in Great Britain.

When and by whom linen paper was invented is a secret, which Polydore Virgil owns he could never trace. Scaliger will have it to have been found out by the Germans. Maffei affirms it certain, that the invention is owing to the Italians. Others ascribe it to some refugee Greeks at Basil, who took the hint from the manner of making cotton paper in their own country. Conringius takes the Arabs to have first brought it among us. Perhaps the Chinese have the best title to the invention; who for many ages have made paper much after the same manner; and even, in some provinces, of the same materials, viz. hemp, &c. Vide Polyd. Virg. de Inventor. Rer. lib. ii. cap. 8. Secund. Scaliger. p. 7. Fabric. Bibl. Antiq. cap. 9. sect. 21. Istor. Diplom. lib. ii. Bibl. Ital. tom. ii. p. 253. Phil. Trans. N° 288. p. 1515. Conring. Epist. ap. Act. Erud. Lips. an. 1720. p. 94. Savar. D. Comm. tom. ii. p. 963. Du Hald. Deser. Chin. tom. i. p. 363.

Linen paper appears to have been first introduced among us towards the beginning of the fourteenth century.—The learned Conringius denies, that there are many manuscripts of this paper above four hundred years old; with whom agrees the count Maffei, who finds no marks of its use before the year 1300. Vide Conring. Epist. ap. Act. Erud. Lips. an. 1720. p. 94. Maffei Istor. Diplom. lib. ii. Bibl. Ital. tom. ii. p. 253.

Some indeed go much farther back; and take the *libri lintei* mentioned by Livy, and other Roman writers, to have been written on linen paper; but Guilandinus, and after him Allatius, and others, have sufficiently refuted this notion; and shewn, that the *libri lintei* were written on actual pieces of linen cloth, or canvas, prepared for this purpose, such as painters still use; and not on paper made of linen rags. Vide Liv. Dec. 1. lib. iv. Plin. Hist. Nat. lib. xiii. cap. 11. Prisc. L. Ant. tom. ii. p. 85. Guiland. Papyr. Memb. 25. Salmuth. ad Pancirol. lib. ii. tit. 13. p. 253.

Others run into the contrary extreme, and make paper the invention of a very late date. The Jesuit Inchofer dates

its origin about three hundred years ago; with whom agrees Milius, in his "*Hortus Philosophicus*," who maintains, that the art of making paper was not invented till about the year 1470. Of the same opinion seems Ray, who tells us the art of making this paper was not known in Guernsey till the year 1470, and when two persons, named Anthony and Michael, first brought it to Basil, out of Galicia in Spain. In effect, if the invention be owing to the refugee Greeks at Basil, who fled thither after the sacking of Constantinople, it must at least be posterior to the year 1452, when that city was taken. Some add a farther argument for the novelty of paper, drawn from the novelty of hempen cloth, which Rabelais, who died in 1553, mentions as first found out about a hundred years before him; and which was so scarce in the time of Charles VII. of France, who died in 1461, that the queen, his wife, was the only woman in France that had a couple of shifts of it. Vide Mabill. de Re Diplom. lib. i. cap. 8. Reimm. Idea Syll. Antiq. Liter. p. 313, seq. Balbin. Miscell. Hist. Bohem. cap. 22. Aët. Erud. Lipf. 1682. p. 243. Ray Hist. Plant. lib. xxii. Phil. Transf. N° 288. p. 1515. Naudæan. p. 82. Nouv. Rep. Let. tom. xxvi. p. 571.

But these suggestions are refuted by Mabillon, from the testimonies of writers prior to the time here spoken of, and from many manuscripts of about four hundred years old, which are written on linen-paper. The Jesuit Balbinus produces divers instances of paper manuscripts, written before the year 1340. An ingenious writer of our own country assures us, he had a piece of paper which agreed well with the charter dated in 1358, in the thirty-second year of Edward III. He adds, that in the archives of the library belonging to the dean and chapter of Canterbury, is an inventory of the goods of Henry, prior of Christ-church, who died in 1340, written on paper; and that in the Cotton Library there are several writings on our paper, in the times of most of our kings and queens, as high as the fifteenth of Edw. III. which coincides with the year 1335. And Dr. Prideaux assures us he has seen a registration of some acts of John Cranden, prior of Ely, made on paper, which bears date in the fourteenth year of king Edward II. that is, anno Domini, 1320. Mabill. loc. cit. Balbin. lib. cit. Phil. Transf. N° 288. p. 1515. Prid. Connect. p. 1. l. 7. p. 710.

Add, that the invention of paper may appear more modern than it is, because records were not used to be written on it, but it was a considerable time confined to letters, and other fugacious compositions; which is so true, that, to this day, few instruments of any consequence are written on it, though it have been so long in use. It is even alleged, that Peter, the venerable abbot of Cluny, who died in 1157, has a passage in his book against the Jews, which plainly indicates paper books to have been then known; on the authority of which Valesius, in his notes on the panegyric of Berengarius Augustus, scruples not to make paper upwards of 500 years old.

Father H. roundin assures us, he had seen records or diplomas on it prior to the 13th century. But this will hardly be credited. Count Maffei assures us, that in all his researches he could never meet with one more ancient than the year 1367. It is highly probable the learned Jesuit mistook a cotton manuscript for a linen one: a mistake easily made, as the chief difference between the two consists in the greater thinness of the linen paper. But it is known we have linen papers of very different degrees of thickness; and the like may be said of those of cotton. Vide Maffei Ist. Diplom. lib. ii. Bibl. Ital. tom. ii. p. 253, seq.

The invention, according to Prideaux, seems to have

been brought from the East; because most of the old manuscripts, in Arabic, and other Oriental languages, are written on this sort of paper; some of which are certainly much older than any of the dates above-mentioned. This author thinks it most probable, that the Saracens of Spain first brought it out of the East into that country; from whence it was propagated through the rest of Europe.

PAPER-Making. Nature presents us, as we have already observed, with a variety of substances from which paper may be made, as linen or hempen rags, the stalks of nettles, straw, hay, and the down of thistles. It may be also made of cotton, or white woollen rags, though such paper would not serve for writing, because of its hairiness. Of all these substances, linen or hempen rags alone are employed by the manufacturers, except a small quantity of cotton rags, which are sometimes mixed with the linen for inferior purposes.

The chief process of making paper consists in separating the fibres of the rags, by grinding, into exceedingly fine and short filaments; which being mixed with water, till they make a fine pulp, may be taken up in a very thin and even layer upon a mould of wire cloth. Now by the draining away of the water through the wire, the filaments are left, interwoven or felted so completely among each other, that they will not separate without breaking, and when dry will make a sheet of paper; the strength and quality of which depend very much upon the materials it is made from, and the equality of length and size to which the filaments are reduced by the grinding, which equality alone can cause them to float equally in the water of the pulp, and thus distribute themselves fairly and equally over the wire mould when taken up by it. For writing paper, a fine white colour is necessary, and this is obtained either by using the whitest rags by themselves, or by a chemical process of bleaching.

The incalculable advantages which the moderns have derived from the art of printing, would have been only imperfectly known, but for the invention of linen rag paper. A more plentiful and economical substance could not be conceived than the tattered remnants of our cloths, linen worn out, and otherwise incapable of being applied to the least use, and of which the quantity every day increases: nor could a more ready operation be imagined, than a few hours trituration in a mill. It has been observed by a French writer, that the dispatch of the processes of paper making is so great, that five workmen in a mill may furnish sufficient paper for the continual labour of 3000 transcribers.

The art of printing would have been comparatively of little importance, without having the means of procuring a proper material to receive the impressions. Whilst the Egyptian papyrus was the only kind of paper, it would have been impossible to have procured it in sufficient quantities to have made large editions of books. The cotton paper, though in a progressive stage of improvement, was but a rude and perishable article, unfit for any of the nice purposes to which paper is now applied.

The perfection of the art of paper-making depended upon finding a material which could be procured in sufficient quantities, and which would be easy of preparation. Such is the paper now in use, of which we shall endeavour to describe the manufacture.

The operation of paper making admits of three divisions, viz. the preparation of the rags, the forming of the sheets, and the finishing of the paper. The succession of the several processes is as follows: 1. The rags are washed, or dusted, if they are dirty; then sorted into many qualities proper for different purposes. 2. The rags are bleached, to render them white; but this operation is sometimes deferred to the next stage of the process. 3. The washing engine of the paper

mill is employed to grind the rags, in water, till they are reduced to a coarse or imperfect pulp, called *half stuff*, or *first stuff*, in which state the bleaching is sometimes performed; or at other times it is bleached in the washing engine during the grinding. 4. The *half stuff* is again ground in the beating engine, and water added in sufficient quantity to make a fine pulp, which being conveyed to the vat, the preparation of the rags is completed, and the pulp or stuff is ready for making the sheets. 5. This is done by a workman who takes up a quantity of pulp upon a mould of fine wire cloth, through which the water drains away, and the pulp coagulates into a sheet of paper. 6. Another workman takes the sheet of paper off from the wire mould, and receives it upon a felt; he then covers it over with a second felt, evenly spread out; and continues this operation, which is called *couching*, till he has made a pile of sheets called a *post*, containing six quires. 7. The post of paper, with the felts, is placed in the *vat-press*, and the whole is subjected to a strong pressure, to press out the superfluous water, and give the paper a solidity and firmness it would not otherwise have. 8. The pile of paper is removed from the vat-press, the felts taken out from between the sheets, and they are pressed again by themselves, for a certain time, in a screw press. 9. The sheets are taken from the press, and hung up, five or six together, on lines in the drying loft, till dry. The paper is now made, and only requires to be finished; but it should be observed, that the greater number of the processes of finishing are only performed upon fine writing paper, common printing paper being ready for packing up when dried. 10. The paper, in five or six sheets together, is dipped into a tub of fine size, and afterwards pressed to force out the superfluity; it is then dried again in the drying loft; but in printing papers this process is rendered unnecessary, by sizing the stuff whilst in the engine, and adding certain ingredients. 11. An examination of each individual sheet of the paper is made, all knots and burrs are removed, and the bad sheets taken out. 12. A very large pile of paper is made, and pressed with a most immense force, to render the sheets flat and smooth. 13. The pile is taken down, sheet by sheet, and another made, without turning the sheets over: by this means new surfaces of the sheets are brought in contact with each other, and the pile being again subjected to the press, the surface of the paper is improved. This operation is called *parting*, and is repeated two or three times for the best papers. The paper is now counted into quires, folded and packed up into reams for market.

The strength and tenacity of paper depend upon the staple or fibre of the materials from which it is made. Rags of new cloth, and cordage, compose a tougher and stronger paper than old rags, which make a soft and pliable paper. The first of these materials presents a great variety, on account of the quality of the hemp or flax of which it is fabricated. Rags of fine new cloth, whether raw or bleached, stand in the first rank, after which old rags, cordage, &c. may be classed.

The sorting of the rags is of no small importance in the art of making paper; for unless the rags, which are ground at the same time in the engine, are all of the same quality, both as to substance and condition, the finest and best parts will be ground away in the mill, and carried off by the water before the coarser are sufficiently reduced to make a fine pulp. For this reason, in the sorting of the rags which are intended to make fine paper, the hems and seams should be kept apart, and the coarseness of the cloth should be considered. That cloth which is made of tow, should be separated from that which is made from the longer fibres; cloth of hemp from cloth of flax; and lastly, the degree of wearing in the

cloth should be attended to. For if rags, almost new, are mixed with those which are much worn, the one will not be completely reduced to a pulp, whilst the other will be so attenuated as to be carried off by the water, and pass through the hair strainers of the engine; hence there must be a considerable waste in the operation, a real loss to the manufacturer, and even to the beauty of the paper; for the particles first carried off by the current of the water, are perhaps those which give it that smooth velvet softness which is so great a recommendation. When the sorting is imperfectly performed, the pulp or stuff is found to have cloudy parts floating in it, owing to some masses being less reduced than others. This produces those cloudy papers wherein are seen by intervals parts more or less clear, and more or less weak, occasioned by flakes assembled on the wire of the mould, which are not sufficiently tempered and diluted to incorporate with more fluid parts.

But as it is necessary, in many cases, to mix the different qualities of rags together, to produce various kinds of paper, this should be done by reducing the different sorts of rags separately in the mill, as also the hems and threads of the stitching, because the sewing thread, being never so much worn as that of the cloth, and not so easy to be reduced, forms filaments in the paper. When the rags, unequally disposed for trituration, have been ground apart, the different pulps may be mixed together without inconvenience, and will be found homogeneous or alike, each having been ground during the time that was necessary for the state of the rag.

Without this precaution the finest particles will be always lost, and of course the beautiful quality of the paper will be altered by the coarsest. Therefore this care in sorting the rags produces a great beauty of the paper, without hurting its goodness. It will, besides, be attended with the advantage of mixing a pulp, which will form the strength of the paper, with another which will give it softness and lustre; and thus two qualities may be united which otherwise existed separately.

There are people in London, who, by dealing very extensively in rags, have it in their power to observe these precautions in sorting, and to sell separately all the different qualities to the paper makers. The same may be said of those great manufacturers who have the perfections of their work at heart. As to small country mills, it is scarcely possible for them to make so great a choice. They are often obliged to lay up for fine many rags which are properly middling, and their middling may with better reason be reserved for making the coarser sort of paper.

The people who go about the streets to buy up rags and old garments, sell them to the great dealers, who for the London market employ women to sort them into five sorts, which are denominated Nos. 1, 2, 3, 4, and 5, according to their respective qualities. No. 1 being superfine, and wholly linen, is used for the finest writing papers. The other sorts have different degrees of fineness down to No. 5, which is completely canvas, but is proper for making inferior printing papers, when it has been bleached to a good colour. There is also rag bagging, which is the materials of the strong canvas sacks the rags are sewed up in for carriage; and coloured rags, which consist of cotton, and are of all colours promiscuously mixed; but the blue are generally sorted out, for the purpose of making blue paper. The rag bagging and cotton rags are only fit for common papers. The rags are first put into a machine, called a *duster*, made in the form of a cylinder, four feet in diameter and five feet in length. It is all through covered with a wire net, and put in motion on pivots at its ends by a connection with some

part of the machinery. The whole is inclosed in a tight close box to keep in the dust. A convenient quantity of rags, before the sorting, is inclosed in the cylinder of the dufter, and the rapidity of its motion separates the dust from them, and it passes through the wires into the box. It is of considerable advantage to use the dufter before sorting, as it makes that operation less pernicious to the people.

The sorting is performed by women and children, who are seated on benches, in a large room full of old linen, before a chest or box, which is divided into six cases, to receive as many different sorts of rags. Each woman has a piece of pasteboard, hung from her girdle, and extended on her knees, upon which, with a long sharp knife, she unrips seams and stitches, and scrapes off all filth.

Whatever can be used, after being well examined, is distributed into one of the six cases, according to the degree of fineness, and the women throw the rest at their feet. The six cases are for the six different sorts of rags: the superfine; the fine; and stitches of the fine; the middling; the seams, and stitches of the middling; and the coarse; without including the very coarse parts, which are totally rejected, at least for the making of white paper, but may serve for white-brown paper; but even for this purpose they should be mixed up with a large parcel of coarse linen. Old paper may also serve for the same use, but the waste is considerable; it is therefore reserved for pasteboard, in the manufacture of which, the stuff being worked less time in the engine, and with less force, though with the same water, it will lose much less than if worked sufficiently to make paper. Besides, paper that has been once sized still gives the pulp a viscosity, which ought to be guarded against, as it prevents the fibres floating so completely detached in the water as is necessary to make them distribute themselves sufficiently equal and regular upon the wire mould, to make a true and even sheet of paper.

Paper intended for bills of exchange, or other commercial and legal instruments, ought to be tough, in order that it may not be easily torn, when made as thin as it is necessary to be, for the ease of conveyance by post. For this, paper materials of the best quality must be entirely, or in large proportion, employed; and the price which the consumers are disposed to pay for the article is sufficient to allow the best materials, and still indemnify the manufacturer for his care and industry.

Common papers also require to be more or less tough, according to their thickness, and the use to which they are applied; but a clear white colour is sought in paper of every description, whether for writing or printing. The manufacturers of paper were formerly obliged to attend to the colour of the rags in the sorting, as well as to their qualities; but of this care they are now in a great measure relieved, by the introduction of bleaching, which enables them to produce the finest paper, in point of colour, from any kind of rags. They have only therefore to find such materials as will make paper of a strong texture, and a fine even surface, knowing they can produce colour at pleasure. To bleach the rags by the oxymuriatic acid gas, they are first washed in hot water, by a fulling mill, such as is used for scouring cloth: this removes the dirt, and they are put into a receiver or chamber, made of wood, in a cubical form, and the joints air tight. It is provided with several stone retorts, which being filled with a mixture of manganese, with two-thirds its quantity of sea-salt, and a quantity of sulphuric acid equal to the salt, will, when moderately heated by a small sand-bath furnace, throw into the receiver a gas which quickly discharges any colour the rags may contain. This process, which is very similar to that used for bleaching

cotton thread, was invented by Mr. Campbell, who had a patent for it in 1792. In his specification, he directs that the rags should, before they are put into the receiver to be bleached, contain about their own weight of fair water, the super-abundant water being pressed out. The rags should first be opened by a machine, called by the cotton manufacturers a *devil*, or some machine, of that nature, and they are to be distributed in the receivers, in layers spread on frames, so that they will not come in contact with each other, or they may be placed in the body of the receiver, and have stirrers or agitators, provided to expose every part of them to the action of the bleaching gas.

After the process, which must be concluded as soon as ever the rags are sufficiently bleached, lest the gas should act upon and injure their quality, they are to be washed in water, and will be ready for the mill. Some manufacturers think that this mode of bleaching the rags makes them rotten, and injures the quality of the paper, which it certainly does if carried too far, though there is no doubt of the advantages of the process if well conducted.

The bleaching process has given rise to great complaints from the printers, as many printing papers are now made from cotton rags. The oxygenated muriatic acid being applied for the purpose of obtaining dispatch and delicacy of colour, produces a paper of a good appearance from inferior staple. Nothing can be more perplexing to a printer, nor more detrimental to his labours, than this kind of bleached paper; for although it may be thick, and seem strong in the ream, no sooner does the water penetrate through it, than it loses its adhesive quality, and becomes so loose and soft as scarcely to bear handling, and in working under the press sinks down into the cavities of the letters, leaving a part of its substance behind, after every impression, until it so clogs the type, that the work is rendered scarcely legible. Nor is it less exceptionable in point of durability, as it must moulder away in a little time, with the common use that popular books generally undergo. Notwithstanding this it must be allowed, that if by bleaching the paper makers can produce a bad article from such materials as were otherwise of no use, they are also able to improve their manufacture when they use the same materials as formerly. It is found most advantageous to bleach the rags in the state of half stuff, that is, when they have been once worked by the mill, as the fibres being by that means separated, the gas has greater access to the interior parts, and they are bleached quicker, so as to have less danger of injury to particular parts, by too long an action of the gas. Another method of bleaching is by muriatic lime put into the washing engine, which for printing papers is the best mode of any. We shall describe it in the process of washing.

The engines now used in the paper mills are constructed on such a powerful principle, that they are capable of reducing the strongest and toughest rags to pulp in a moderate time; whereas the old machines were not able to work the rags without fermenting them, as a previous process. The following extracts from a French work, on the art of making paper, will shew the manner in which it was conducted 60 years ago.

“The rags, being sorted, are put into a large stone vat, sixteen feet long, ten broad, and three deep; water is poured upon them to the top during ten days, and eight or ten times every day without stirring them. They are afterwards left to rest the same number of days, and sometimes more or less, without pouring water upon them. Then being turned over, the centre is brought to the surface, to facilitate the fermentation; and after being turned again, they are still left fifteen or twenty days in ferment-

station, so that the rotting may last five or six weeks; the term is not fixed, but when the heat becomes so great, that the hand, thrust in, cannot endure it above some seconds, it is judged that it is time to stop it.

"In mills, which have but few rags to work upon, they are left to rot longer, because the heaps being smaller, heat less, and with more difficulty; so that nothing can be justly determined of the time proper for the rotting part. It depends also on the quality of the rags; the finest linen does not rot so soon as the coarse; and linen that has been worn with more difficulty than new, because the internal humidity, that disposes the fibres to fermentation, is more considerable in new or coarse, than in fine or worn linen. Such as are more or less strong, more or less worn, resist the action of rotting in different degrees, some being spoiled, when others have not gone through the first fermentation: so that the rags, which have been sorted with great care, ought to be left to rot together, to avoid the risk of altering the whole parcel, by the mixture of a portion of rags quite different from the rest. When champignons grow on the heaps of rags, it is reckoned to be a sign of their being well rotted.

"Besides this, there is another method for disposing of the rags in the place for rotting and fermenting them. Having been wetted with water, a heap is made of them in a corner of the vaulted room, which is destined for that purpose. They are watered from time to time, and when sufficiently heated, are transported into another angle of the same room, so that what was at the top of the first heap, is now laid under the second, and care is taken to throw water upon them from time to time. When this heap takes heat again, it is transported to the third corner, where, having fermented again, it is carried into the fourth angle; observing always to lay those rags under the heap that were at the top of the foregoing, and to water them often, for a reddish water will come from them, which it is very necessary to clear the rags of. When the heap in the first corner is brought away, another is formed in the same corner, which passes in its turn to the several corners of the room.

"Some, to accelerate the operation of rotting and fermenting, throw lime upon the rags. Perhaps a very small quantity of lime may be used: but if too much is laid on, the corroded rags will be too soon reduced into a pulp, and will pass through the strainer with the water, which ought to carry off only their filth, and will occasion a considerable waste. The use of lime, for the purpose of rotting rags, is absolutely prohibited in France.

"Fermentation, or rotting, makes the paper even, curdled as it were, soft, and gives it weight; if stopped too soon, the paper becomes crude, hard, light, stiff, requires more time to be worked, and the *secula*, or pulp, does not so easily form a coagulation on the wire of the mould. It is sometimes observed, in regard to good rags that have not rotted, that the *secula* is, as it were, enveloped in a viscid substance, which prevents its uniform precipitation; and this proves that rotting helps to clear off the unctuous matter in rags. If, on the contrary, the rags were left to ferment too long, a considerable waste would be occasioned, and more matter required for the same quantity of paper, because the parts attenuated by fermentation, would be too readily carried off by the washing. And lastly, if they were left to heat too long, they would be reduced to dust, and burn into smoke and ashes."

The action of rotting was, at that period, thought necessary for abridging the labour of making paper, and facilitating the operation of the mill; but several advantages are

procured by dispensing with it, now we are able to destroy the texture of the cloth and reduce it to pulp, without previously corrupting its substance by rotting it; the paper is much flouter, is less liable to break, and is also whiter, for the fermentation gave a yellowish hue to the surface of the rags, which the mill could not take out without difficulties, and never could entirely, if the rags were too rotten.

We now come to describe the structure of paper mills.

In England they now work with cylinders, or engines, an invention which was brought from Holland many years ago, and found to be so great an improvement, that it has been universally adopted. The old mills, which are still in use in some parts of the continent, actuate a number of stampers, or pestles, which pound the rags in wooden mortars till they are reduced to a pulp. These mortars are cut out in a block of heart of oak, well seasoned, the cavity being of an oval figure, about eighteen inches broad, thirty inches long, and eighteen or twenty in depth; the bottom concave, and lined with an iron plate an inch thick, eight inches broad, and thirty long, shaped inwards like a mould for a salmon, with the head and tail rounded. In the middle of the mortar is a cavity beneath the plate, and four or five grooves are cut, forming channels which lead to a hole cut from the bottom of the cavity quite through the block: it is covered by a piece of hair sieve fastened on the inside. This plate is grooved to make teeth, on which the teeth of the hammers act, to cut the rags in pieces. The use of the hair sieve is to prevent any thing from going out except the foul water. Two hammers or pestles work side by side in each mortar, and are lifted alternately by the mill: they are sometimes made in the same manner as the stampers of an oil mill, to lift perpendicularly. In other mills they are large hammers moving on a centre like a fulling mill, and lifted by cogs upon the mill shaft in the same manner. The mortars are kept constantly supplied with fair water, by little troughs, leading from a cistern, which is kept full by small buckets affixed to the floats of the water-wheel; these, when they have raised the water to the top, pour it out into the cistern, in the same manner as the Persian wheel.

This rude and imperfect machine operated very slowly, and suffered a great part of the rags to escape being reduced, whilst other parts were beaten too much. It is not now to be met with in England, the Dutch engines having taken their place, to the great improvement of the paper trade; these are turned by water mills, as they require a very great power to actuate them, though their performance is far greater, with the same power, than the mortars.

The construction of the mills is varied in different situations; but to explain the best kind, we have in *Plate 1. Paper Mill*, given a drawing of one made with iron wheels, *fig. 1.* being an elevation, and *fig. 2.* a plan: the same letters of reference are used in both. The water-wheel which gives the motion cannot be seen, as it is situated beneath the floor, but its dimensions are marked by four dotted lines AAAA: in the plan it is enclosed between the three walls of the house PPR, and a fourth wall Q, which is built up across the house, to support the floors N and O, on which the engines stand: the wall R has arches in it to admit the water of the stream to the wheel, a proper gate being fixed to regulate its quantity: the axis of the water wheel, which is of cast iron, comes through the wall Q, and has a large cog-wheel B upon it, which is the full size of the water wheel, and by the paper makers is termed the *master-wheel*; the extreme end of the shaft is sustained in a bearing, which lays on a beam G G, supported on a wall of masonry. The pinion C, called the

wallower, is turned by the maller-wheel B, and on its axis is fixed the large spur-wheel D, called the *fly-wheel*, giving motion to the two pinions E, F, of the engines K and L: the shaft of the wheel D and pinion C are supported at one end in a frame H H I, and the other, in a bearing fixed in the wall Q. The engines K and L are placed on the floors N and O upon different levels, as shewn by *fig. 1*, the bottom of L being higher than the top of K, so that the contents of L may be let down through a plug-hole in the bottom. The upper engine L is called the *washer*, where the rags are first worked coarsely, with a stream of water running through them to wash and open their fibres; after which washing they are called *half fluff*, and are then let down into the beating engine K, to be ground, and reduced to a finished pulp, proper for moulding into sheets of paper.

By the arrangement of the wheels of the mill, the cylinders, *k* and *l*, of the two engines are contrived to make about from 120 to 150 revolutions *per* minute, when the water-wheel moves with its proper velocity; though the beating engine revolves much quicker than the washer, its pinion, F, having only 24 teeth, while the washer, F, has 28. The great wheel, B, has 196 teeth, and the pinion, C, 38 teeth; therefore it makes about $5\frac{1}{2}$ turns, for one of the water-wheel. The wheel D has likewise 196 teeth, and turns the washer, F, of 28 teeth about 36 times, for once of the water-wheel; and the beater, E, about 42 times. M is a cog-wheel, put in motion by the teeth of the great wheel B: on the extremity of its spindle is a crank *a*, which, by a connecting rod, gives a reciprocating motion to a lever *c d*, for the purpose of working two pumps, *e, f*, which raise water into a cistern *h*, drawing it from the water of the mill-dam by a suction-pipe *g*. These pumps raise up a constant stream of fair water, which is necessary to be kept running through the rags in the washing-engine, to carry away the dirt separated from them by the operation.

The engines are shewn at K and L, in the plan: each consists of a wooden vat or cistern, divided by a partition in the middle; and in one of these divisions, their cylinders, *k* and *l*, are teen. These are provided with teeth or cutters, which act against similar teeth fixed in blocks, situated beneath the cylinders, to cut the rags between them, when they revolve. The structure of an engine is more minutely explained by *figs. 1, 2, 3, 4, &c.* of *Plate II.*; *fig. 1* being a section through the length of the engine, and *fig. 2*, a horizontal plan. The large vat or cistern, A A, is of an oblong figure on the outside, the angles being cut off; but the inside, which is lined with lead, has straight sides and circular ends. It is divided by a partition B B, also covered with lead. The cylinder, C, is fixed fast upon the spindle D, which extends across the engine, and is put in motion, as before described, by the pinion E, placed on the extremity of it. The cylinder is made of wood, and furnished with a number of teeth, or cutters, fixed fast on its circumference, parallel to the axis, and projecting about an inch, as is shewn on a larger scale at *fig. 5*. Immediately beneath the cylinder, a block of wood, H, is placed, and provided with similar cutters to those of the cylinder, which, when they revolve, pass very near the teeth of the block, but do not touch; the distance between them being capable of regulation, by elevating or depressing the bearings on which the necks, D, D, of the spindle are supported. These bearings are made on two levers, F, F, which have tenons at their ends, fitted into upright mortises, made in short beams, G, G, bolted to the sides of the engine. (See also *fig. 3.*) The levers, F, F, are moveable at one end of each,

the other ends being fitted to rise and fall on bolts, in the beams G, as centres. The front one of these levers, or that nearest to the cylinder C, is capable of being elevated or depressed, by turning the handle of the screw *b*, which, as shewn in *fig. 3*, acts in a nut *a*, fixed to the tenon of F, and comes up through the top of the beam G, upon which the head of the screw takes its bearing. Two brasses are let into the middle of the levers, F, F, and form the bearings for the spindle of the engine to turn upon. The screw, *b*, is used to raise or lower the cylinder, and cause it to cut finer or coarser, by enlarging or diminishing the space between the cutters in the block and those of the cylinder.

Near K, *figs. 1* and *2*, is a circular breasting made of boards, and covered with sheet-lead: it is curved to fit the cylinder very truly, and leaves but very little space between the teeth and breasting. An inclined plane, K, leads regularly from the bottom of the engine-vat to the top of this breasting; and at the bottom of it the block, H, is fixed. The engine is supplied with water by a pipe, Q, bringing it from the pump: this pipe delivers it into a small cistern, M, adjoining, and communicating with the engine. The pipe has a cock, P, to stop the entrance of the water, when required, or to regulate the quantity of its discharge. The small cistern has a grating fixed across it, covered with a hair-strainer, to catch any extraneous matter, which may come in with the water; or a flannel bag is sometimes tied over the orifice of the cock P, through which all the water must be filtered. When the engine is filled with water, and a quantity of rags put in, they are, by the revolution of the cylinder, drawn between its cutters and the teeth of the block H. This cuts them in pieces; then, by the rapid motion of the cylinder, the rags and water are thrown over the top of the breasting, upon the inclined plane: in a short time, this raises more rags and water into that part of the engine-vat; and the tendency to restore the equilibrium puts the whole contents of the vat in slow motion, down the inclined plane K, and round the partition B B, by which they come to the cylinder again in about the space of 20 minutes; so that the rags are repeatedly cut and chopt in every direction, till they are reduced to a pulp.

This circulation is of advantage, in turning the rags over in the engine, and causes them to present themselves to the cutters in a different direction every time; for as the cylinder cuts or clips in straight lines, in the same manner as a pair of shears, it is requisite to cut the rags across in different directions, to reduce them to a pulp. The manner of the cutting is this: the teeth of the block are placed rather inclined to the axis of the cylinder, as shewn by *fig. 4*, but the teeth of the cylinder are parallel to its axis; therefore, the cutting edges, when they meet, are at a small angle, and come in contact first at one end, and then successively the contacts proceed along to the other end, so that any rags interspersed between them are cut in the same manner as they would be between the blades of a pair of shears. Sometimes the plates or cutters, *k*, in the block are bent to an angle in the middle, instead of being straight, and inclined to the cylinder: in this case, they are called elbow plates, and of course the two ends are both inclined to the axis of the cylinder in opposite directions. In either case, the edges of the plate of the block cannot be straight lines, but must be curved, to adapt themselves to the curve which a line traced on the cylinder will of course have. The plates or cutters of the block are united, by screwing them altogether, and fitting them into a cavity cut out in the wooden block H; their edges are bevelled away on one side only, as shewn at *k* in the section, *fig. 4*. The block is fixed in its place by being made dovetailed, and truly fitted into the

bottom of the cistern, so that the water will not leak by it. The end of it comes through the wood-work of the chest, and projects a small distance on the outside of it, being kept up to its place by a wedge, so that by withdrawing this wedge, the block becomes loose, and can be removed, to sharpen the cutters, as occasion requires. This is done on a grindstone, the plates being first separated from each other.

The cutters of the cylinder are fixed into grooves, cut in the wood of the cylinder, at equal distances from each other round its circumference, in a direction parallel to its axis: the number of these grooves is twenty; and for the washer, each groove has two cutters or bars put into it; then a fillet of wood is driven fast in between them, to hold them firm; and the fillets are kept fast by spikes driven into the solid wood of the cylinder. The beater is made in the same manner, except that each groove contains three bars, and two fillets, as shewn in *fig. 5*.

In the operation of the cylinder, it is necessary that it should be inclosed in a case, or its great velocity would throw all the water and rags out of the engine. This case is a wooden box L L, inclosed on all sides except the bottom: one side of it rests upon the edge of the vat, and the other upon the edge of the partition B B. The lines, *c, c*, represent the edges of wooden frames, which are covered with hair or wire-cloth; and immediately behind these, the box is made with a bottom, and a ledge towards the cylinder, which makes a complete trough. The dark spaces, *e, e*, in *fig. 1*, shew the situation of two openings, or spouts, through the side of the case, which lead to flat lead-pipes, *b, b*, *fig. 2*, which are placed by the side of the vat; the beam, F, being cut away for them. There are waste pipes, to convey away the foul water from the engine; for the cylinder, as it turns, throws a great quantity of water and rags up against the sieves: the water goes through them, and runs down into the trough at *e e*, and from thence into the ends of the leaden pipes, *b, b*, *fig. 2*, by which it is conveyed away: *d, d*, *fig. 1*, are grooves for two boards, which, when put down in their places, cover the hair-sieves, and stop the water from going through them, if it is required to retain the water in the engine. This is always the case in the beating-engines, and therefore they are seldom provided with these waste-pipes, or at most on one side only; the other side of the cover being curved, to conform to the cylinder. Except this, the only difference between the washing-engine and the beater is that the teeth of the latter are finer, having 60 instead of 40 bars on its circumference; and it revolves quicker than the washer, so that it will cut and divide those particles which pass through the teeth of the washer.

In small mills, where the supply of water is limited, they frequently have but one engine, and use it both for washing and beating, by setting the screw so as to let the cylinder down and make its teeth cut finer; but the system of all considerable works is to have two engines, or four, if the supply of water is sufficiently great. We have seen a very capital paper mill containing five engines, where three of them are beaters and two workers; because the beating takes so much more time, than when the numbers are equal, the washers will often do too much for them, and they will have to stand still. A mill to drive four engines is generally made double, that is, it has two water-wheels, and all the machinery shewn in the plan; and if either of these give motion to three engines, they are arranged rather differently: thus the two beaters are placed on the same level with each other, and this removes them to a greater distance asunder than shewn in *fig. 1*, *Plate I.*; so that the ends of the two engines,

when placed on the same floor or platform, will just touch each other. The washer is then placed on the opposite side of the wheel D, *viz.* where the word *plan*, *fig. 2*, is written, its pinion being upon the summit of the wheel, which raises it to the proper level: the vat of the washer has a valve or cock in each end, to let out its contents into either of the beaters at pleasure.

The mills with spur-wheels, such as is given in our drawing, are not very common, though they work much better than the ordinary arrangement of the wheels for a paper mill: in this the shaft of the water-wheel has a large face, or crown-wheel, fixed upon it, which actuates a wooden trundle fixed upon a vertical shaft, proceeding upwards through the floor of the mill, and there it carries two large horizontal crown or face-wheels, giving motion to the pinions of the engines, which are situated on opposite sides of the upright shafts. It is necessary to have two horizontal wheels, because of the different levels at which the engines must be placed. These mills are generally made in wood, in a very rude and coarse manner, with crown-wheels and large cogs, so that the friction is very great. Their only recommendation to the paper-maker is their cheapness of erection; but this is only on account of their inferior workmanship, for to make a mill in iron with a vertical shaft and bevelled wheels, as they should be to work properly, would be far more expensive than the construction shewn in *fig. 1*, which is therefore adopted by those manufacturers who choose to have their mills made in a complete and durable manner.

The quantity of water which a paper mill can command to turn its engines, generally limits the extent of its trade; and hence the manufacturers should attend to every improvement of the machinery which can increase their effect. Where the supply of water is constant, they work the engines day and night, though the making the paper, as it requires many workmen, is of course carried on in the day time only. This system necessarily requires a large vat to be provided, which is called the *stuff-chest*, and is a general receptacle for the pulp, where it is kept till wanted to be made into paper; at the same time this mixes the pulp of different day's work together, and produces an uniformity in the quality and colour of the paper, which is a great recommendation for printing large editions of books.

A very large and capital paper mill, at Maidstone in Kent, which is the principal seat of the paper trade in England, is worked by steam-engines, and is found to answer very well. The machinery and building of a paper mill should be well made, and firmly put together, otherwise its great velocity, and power, produces a tremor, which in time shakes every thing to pieces. The noise and vibration of a washing-engine is most tremendous; for when it revolves 120 times *per* minute, and has 40 teeth, each of which passes by 12 or 14 teeth in the block at every revolution, it will make near 60,000 cuts *per* minute, and each of them sufficiently loud to produce the most horrible growling sound which can be conceived. The beater revolving quicker, having 60 teeth, and 20 or 24 cutters in the block, will make 180,000 cuts *per* minute, which is so rapid, as to produce a coarse musical note or humming, which may be heard at a great distance from the mill. This great number of cuts will account for an engine being able, in the course of four or five hours' working, to reduce a quantity of rags to those exceedingly minute filaments, of which paper is composed.

The operation of grinding the rags in the engines requires some management to produce the best effect: the operation of the washing-engine is to open the rags, and to separate their fibres from each other, rather than to cut

them, and at the same time, by the stream of water which runs through, to carry off all dirt. At first putting into the washing-engine, they should be worked gently, not to cut, but only to rub the rags violently, that the water may have the best effect in carrying off the impurities: this is done by raising up the cylinder, so that its teeth do not touch the teeth of the block, for if the washer cut and divided the rags too much in the first instance, the water would carry away a considerable portion of the finest parts. The cock is at this time opened to admit a great stream of water. When this has continued 20 or 30 minutes, the bearing of the cylinder is let down so low, that its weight rests upon the teeth of the cutter, and it now begins to cut the rags in pieces, the supply of water is diminished, and the operation is at first very violent, the rags frequently causing the cylinder to leap up a considerable height. After working about three or four hours, the engine will get to work very steadily, because the rags, though not reduced to a pulp, are cut very small, and make less resistance to its motion: at this period the washing is usually concluded, and the contents of the engine, called *half stuff*, discharged into a large basket, which allows the water to draw away. For some kind of paper it is thought advisable to let the half stuff remain four or five days to *mellow*, or indeed ferment; and if fermentation is at all proper, this must certainly be the best stage for it, when all the mass of rags is brought to an equal state of division of the fibres. The bleaching is, as before-mentioned, sometimes performed upon the half stuff, instead of bleaching the rags previously; but more commonly it is done in the washing-engine, and this is the most convenient method of all, as it requires no apparatus, and takes very little time, puts the manufacturer to no other expence than the bleaching salt (muriate of lime) by which it is performed, and the effect, if well managed, is equal to that of bleaching by the oxymuriatic acid gas, as at first described. After the rags have been washed for four hours, as above-mentioned, if it is required to bleach the stuff in the engine, they stop the water from running in at the cock, and throw into the engine a quantity of bleaching salt, or muriate of lime. For fine rags, one or two pounds, more or less, are used, according to the quantity of rags the engine contains, which is usually one hundred weight: the two sliders, *d, d. fig. 1, Plate II.*, are put down in the cover of the cylinder, to prevent the water getting away. In this state the engine is worked about an hour for the bleaching to take place, and during this time the rags lose their colour; but this does not colour the water, though it is rendered rather white and milky by the salt. The very best rags, when first put into the engine, are of a very yellow and dirty colour; but they become, by the bleaching, a very perfect snow white: the cylinder is usually raised up a very little during the bleaching, which being concluded, the water-cock is opened again, the boards, *c, c.* are removed, and the washing continued about an hour to wash the salt away, which must be done very perfectly, or it will continue to act upon, and injure the quality of, the materials.

The half stuff is next put into the beating-engine, and worked till it becomes a fine pulp, which will generally take four or five hours, water being let into it at proper times, to dilute the pulp to its proper consistence, but no water is let out of the beating-engine as in the washer. The quantity of water requires great judgment, as it has an influence on the quality of the paper; and the kind of water the manufacturer is obliged to employ must be considered. The fairest water is the best for paper-making, on account of the clean and white quality so desirable in the manufacture. The water that dissolves soap best, is also

the fittest for taking the grease out of rags. Paper-makers say that the water which is most beaten, and that which comes from afar, makes a better curdled paper, stouter, and of stronger consistence, as to matter: if this is the case, it is probably because this water has had more time for depositing the slime, and other heterogeneous parts, and that, being more exposed to the air by motion, it is thereby in a better condition for dissolving grease and soap. Water, subject to be mudded by rain, and that which runs through marshy grounds, ought to be avoided. In like manner, a paper mill ought not to be placed below other manufactories or machinery, which, by using the same water, might communicate to it a bad quality. The water of ponds, and rain water, are very good for dissolving soap, and may therefore be used for paper, if in a pure state. Water, impregnated with lime, by having run off from chalky soils, is generally very pure and clear to the eye, and is, therefore, much used for paper-making, but it is apt to deposit a slight incrustation upon the brass wire of the moulds, which they remove by occasionally washing them with vinegar.

For printing papers, the sizing is done in the beating-engine, towards the end of its operation, as we shall describe: the size is necessary to prevent the ink from sinking into the paper like blotting-paper; but printing-ink not being so fluid as writing-ink, the paper can be sufficiently sized in substance, without subjecting the sheets to a separate operation after they are made. The size for the engine is composed of alum pounded very fine, and mixed up with a quantity of oil: about a pint and a half of this mixture, thrown into the engine at intervals, during the last half hour of the beating, is sufficient. In order to give that bloom, or blue cast to the paper, which some kinds have, a quantity of powder blue is frequently put into the engine at the same time. The pulp is now run off into the *stuff-chest* where the different kinds are mixed, and it is taken out as it is wanted, in the vats where the dippers, &c. work to form the sheets.

The moulding of the paper should be carried on in a lofty room, well ventilated, and with a smooth and even ceiling, that the steam arising from the several vats of pulp may not be condensed upon it, and fall in drops, for a single drop falling upon a sheet of paper, whilst it is moulding, will beat a hole through it, or at least spoil it. The people in this apartment work at the *vats*, with *moulds*, *deckles*, *felts*, *vat press*, and *wet press*. The *vat* used to contain the pulp is a tub, generally about five feet in diameter, and two and a half in depth. It is provided, on the upper part, with planks enclosed inwards, and even railed in with wood, to prevent any of the stuff from running over in the operation: a plank, pierced with holes at one of the extremities, is placed across the vat, and resting on the planks which surround the vat, forms a support to rest the mould upon, when a sheet of paper has been made, and it remains here a short time to drain off the superfluous water. The stuff in the vat is kept at a proper temperature, by means of a grate introduced at a hole in the side, and surrounded on the inside of the vat with a case of copper. For fuel to this grate charcoal or wood is used, and frequently, to prevent smoke, the wall of the building comes in contact with one part of the vat, so that the fire has no communication with the room where they make the paper. The paper is made into sheets upon the *mould* and *deckle*. The *mould* is a square frame, or shallow box, made of well-seasoned mahogany, and covered at the top with wire-cloth; its dimensions are an inch or an inch and a half larger than the sheet of paper intended to be made upon it. The wire-cloth of the mould is varied in proportion to the fineness of the paper and the nature of the

stuff. It consists of a number of parallel wires stretched across the frame, very near together, and tied fast through holes in the sides; also a few other stronger wires, extending across in a direction at right angles to the former, and a considerable distance asunder, the small wires being bound down to them by fine wire at the intersections. This may be readily understood, from the examination of a sheet of some kind of paper on which the marks of the wires remain, because the paper is thinner in those places where the wire touched it.

By a modern improvement, these marks, called water-marks, are avoided, and the paper has a smooth even surface. For this the wire is wove in a loom, exactly like cloth, and stretched over the frame of the mould. The wire-cloth is in this case made larger than the intended sheet of paper, and turned down over the sides of the frame, being sewed fast to it by fine wire, so that the cloth is strained tight over the frame. The wove paper, as it is called, when made on these moulds, is a very superior article to the old paper, particularly for books, but a prejudice still prevails in favour of the old paper with lines, which obliges manufacturers still to make it, though by no means so fine or good as the wove.

The *deckle* is a square frame of mahogany, bound with brass at the angles; it is made very thin, and its outside corresponds with the sides of the mould, while the inside is the size of the sheet. This frame is necessary to retain the stuff of which the paper is made on the cloth, and it must be exactly flat, that it may fit upon the wire-cloth of the mould, otherwise the edges of the paper will be ragged and badly finished. The *deckle*, when placed upon the wire of the mould, forms a shallow sieve or mould, in which a quantity of the pulp is taken up, and by the draining through of the water, the pulp is left in a sheet upon the wire. There is no fastening for the *deckle*, as it is moveable, and only held upon the mould, by the workman grasping the mould and *deckle* together in both hands at the opposite sides. This admits of the *deckle* being removed, that the sheet of paper may be taken up from the wire, by applying the mould upon a piece of felt. The *felts* are pieces of woollen cloth, spread over every sheet of paper, and upon which the sheets are *laid*, to detach them from the wire of the mould; they also prevent them from adhering together, and imbibing part of the water with which the paper is charged, transmit the whole of it when placed under the action of the *vat press*. The moulding of the paper is performed by three workmen, the *dipper*, the *coucher*, and the *lifter*. The first of these having filled the vat with pulp, must be attentive to mix it up well; for this purpose, he employs two implements, one of which is a simple pole, and the other a pole armed with a piece of board, rounded and full of holes. This operation is repeated as often as the stuff falls to the bottom. In the principal mills they use for this purpose what is called a *hog*, which is a machine within the vat, that, by means of a small wheel on the outside, is made to turn constantly round, and keep the stuff in perpetual motion.

When the stuff and water are perfectly mixed, it is easy to perceive whether the previous operations have been complete. If the stuff floats close, and in regular flakes, it is a proof that it has been well ground, and the parts of the rags, which have escaped the cylinder of the engine, also appear. The *dipper* stands in a niche, or hollow part of that kind of ledge or table which goes round the circumference of the vat; he holds a mould in both hands, by the two extremities, with the *deckle* applied exactly over the mould, as if only one piece; then inclining it a little

towards him, he dips it into the vat, and brings it up again into a horizontal position. The superfluous part of the pulp flows over on all sides, and the quantity thought sufficient is shaken gently, from the right to the left, and up and down horizontally, until it is equally extended over the whole surface of the mould. These two motions are also accompanied by a slight shake, that serves to fix and stop the sheet. As the water drains through the wire, the fibrous parts of the stuff arrange themselves regularly on the wire-cloth of the mould, not only in proportion as the water escapes, but also as the workman favours this effect, by gently shaking the mould. This done, the mould is immediately laid on the edge of the vat, the *deckle* taken off, and the mould made to slide along the board which is laid across the vat, to the part where the sheet is to be laid or taken off. The board, which is but two inches in breadth where the sheet is laid, is nothing more than a deal board, which runs along the length of the vat, and is pierced with several holes at the extremity, for letting the mould drain into the vat. The *dipper* taking the *deckle* off the first mould, places it immediately on a second, which is given him for dipping in its turn; and the second workman, called the *coucher*, taking the mould off the board that runs across the vat with the left hand, raises it gently, and lays it in an inclined position against one or two small pins, which are driven into the board on the edge of the vat. In this condition the mould remains two or three seconds of time for draining into the vat, whilst the *coucher* extends a felt, on which he applies the mould to take off the sheet, which being done he returns the mould to the *dipper*.

They proceed in this manner, laying alternately a sheet and a felt, till they have made six quires of paper, which is called a *post*, and this they do with such swiftness, that in many sorts of paper two men make upwards of twenty *posts* in a day.

When the last sheet of the *post* is covered with the last felt, all the workmen about the vat unite together, and submit the heap to the action of the *vat press*. They begin at first to press it with a middling lever, and afterwards with a lever about fifteen feet in length.

The *dipper* should be attentive, in distributing the matter on the mould, to reinforce the corner the *coucher* is to take hold of, in raising and extending the sheets; for without this precaution he would break a great many. Also, if he takes up too much matter with his mould, if he does not equally extend it, or if he strikes his mould against the drainer. In all these cases the matter is accumulated in certain parts of the mould, producing something like ridges in the paper, or if he lets the matter rest on the mould, and does not distribute it immediately, there will be parts of unequal thickness. When the vat is too hot, the stretching out of the sheet will be ill performed, because the water evaporates too soon from the mould. Add to this, that in letting the matter run towards one of the edges, by not giving his arm a regular motion, he may form a feather-edged paper, which may likewise happen if he does not extend his stuff sufficiently; or if the vat be too hot, or the fecula of the pulp is too crude, and does not run well; if his arms are too stiff, and if he gives a bad shake, or if the mould be ill made.

In order to avoid drops of water, which, if they fall upon the paper, will make disagreeable spots, the mould should be raised readily; and as often as the *coucher* returns his mould to the drainers, he ought to be careful to shake his hands behind him; for without this precaution, his fingers, which are wet, would drop upon the sheet already laid, whilst he is covering it with the felt. If he is also too quick

in laying, the air detained and compressed under the sheet occasions a bloating, and makes some parts more clear than others.

In consequence of the construction of the mould, it is easy to perceive that the sheets of paper will take, and preserve, the impression of all the wires which compose it, and of the empty spaces between them. This is seen in examining a sheet of paper before the light, a greater opacity being found on both sides of each brass wire, than towards the midst of the space. This thickness is occasioned by the pulp, which the motion of the mould could not distribute, being stopped by the small wires, and still more by the large cross wires. This defect is completely remedied by the improvement of weaving the wire of the mould like cloth. The traces of the old wires are most evidently perceived on the side of the sheet which was attached to the mould, and on the other side they form an assemblage of rounded risings. In the paper which is most highly finished, the regularity of these impressions is still visible; therefore it is evident, that all the operations to which it is submitted, have chiefly in view to soften these impressions without destroying them; it is necessary, therefore, to attend to the combination of labour which operates on these impressions. The coucher, in turning the mould on the felt, flattens a little the rounded eminences, which are in relieve on one of the surfaces, and occasions, at the same time, the hollow places made by the wire-cloth to be partly filled up; meanwhile the effort which is made in detaching the paper, produces an indefinite number of small hairs on every protuberant part of the sheet. Under the action of the prefs, first with the felts, and then without them, the perfecting of the grain of paper still goes on. The vestiges of the protuberances made by the wires of the mould are altogether flattened, and in consequence the hollows opposite them disappear also, but the traces formed by the interstices of the wire, in consequence of their thickness, appear on both sides, and are rounded by the prefs.

The grain of the paper is often disfigured by the felts when they are too much used, or when the wool does not cover the thread. In this case, when the paper is submitted to the prefs, it takes the additional traces of the warp and the woof, and composes a surface extremely irregular.

The two sides of the felt are differently raised, and that on which the hair is longest, is applied to the sheets which are laid down, and any alteration of this disposition would produce a change in the texture of the paper. The stuff of which the felts are made should be sufficiently strong, in order that it may be stretched exactly on the sheets, without falling into folds, and at the same time sufficiently pliant to yield in any direction, without injury to the wet paper. As the felts have to resist the reiterated efforts of the prefs, it appears necessary that the warp be made strong, of combed wool, and well twisted. On the other hand, as they have to imbibe a certain quantity of water, and to retain it, it is necessary that the woof be of carded wool, and drawn out into a slack thread.

The paper remains in the vat prefs during the time that the next post of paper is preparing, and when it is removed to make room for that, the business of the third workman, called the lifter, begins; it is to take the sheets off the felt, (for they are caused to adhere to them by the action of the prefs,) and then making the sheets up into a second pile; but if the coucher works too fast, and the lifter finds himself hard pressed, he cannot stretch out his sheets exactly upon one another, so as to make a neat and compact pile, which is very necessary to make paper of a regular and equal thickness, when put under a second or wet prefs, which is done as soon as several of the piles are completed, and can be collected together.

This second pressure being made with all the sheets in contact with each other, expresses a great quantity of water from the paper, and gives the sheet a very considerable strength; it also tends to take out those freckles on the surface of the sheets, which were occasioned by the impression of the felt, though it is necessary to have felts in the first pressure, because the paper is then so soft and pulpy, that it would be pressed into a solid mass if the sheets touched each other. The paper remains in the second prefs as long as it can, until another pile is made ready by the lifter. When the paper has undergone these operations, it is not only softened in the surface, but better felted, and rendered more pliant in the interior parts of the stuff. In short, a great part of the water which it had imbibed in the operation of the vat is dissipated. By the felting of paper is understood the approximation of the fibres of the stuff, and their interlacing so as to adhere close together. The paper is felted in proportion as the water escapes, and this effect is produced by the management and reiterated action of the prefs: without this action the paper would be porous, and composed only of filaments without adhesion. When the sheets are very thin, and it is found, after the second pressure, that they are formed by a fecula, which is still so saturated with a great deal of water, that they have little consistence, it is probable that the second prefs will join them to one another, and it is difficult to separate them; indeed they cannot well be taken off singly without tearing a great number. This is a proof that the business of the prefs has been badly conducted. To avoid this inconvenience, it is necessary to bring down the prefs at first gently, and by degrees with greater force, and to raise it as suddenly as possible. By this means the water, which is impelled to the sides of the heaps which has not yet escaped, returns to the centre, the sheets are equally dried, and the operation is executed without difficulty. The separation, sheet by sheet, is not necessary for drying, so that seven or eight may be taken together, which is called forming the pages; sometimes also a less number may do, when the paper is of a large size, but never less than three sheets are hung up together. It is of more importance than we are aware of, that the sheets should thus remain, as it were, pasted several of them together: if they were single, they could not resist the moisture of the size, yet this moisture is sufficient to facilitate their separation; but to prevent their separating when they are hung up to dry, they should be so placed that the pages may receive the wind in the surface, and not in the sides and edges. When the paper is removed from the second prefs, it is taken to the drying lofts, which are very extensive apartments, usually the upper parts of all the buildings of the mill: the sides are formed by luffer boards, which are a kind of lattice or boarding which can be opened or shut, to admit more or less air, at pleasure. The sheets are taken up upon a piece of wood like a T, and hung upon hair lines, stretched across large horizontal wooden frames, called *tribbles*, and these, as they are filled, are lifted up between upright posts to the top of the room, and retained by pegs put in the posts; then another frame being filled, is put up in its turn, and so on till the loft is filled from top to bottom.

The principal care in drying the paper, consists in gradually admitting the external air, and in preventing the cords from imbibing moisture; for this reason the lattices or luffer boards should be constructed with great exactness, and the cords may be prevented from imbibing the water by covering them with wax. In using such cords, the moisture does not continue in the line of contact between the paper and the cord, which prevents the sheet from stretching in that particular place by its weight, and from

obtained several patents during its progressive stages of improvement; but an act of parliament was passed in 1807, to extend the usual term of all these patents to fifteen years from that period, and they then enrolled a specification in the records of Chancery, detailing the machine, in its most improved state, and from this we have taken the following description; though it is scarcely possible to describe such a very complicated machine without figures. The pulp having been prepared, in the usual manner, to due consistence, by the admixture of water, kept in motion in the vat by means of what are denominated hogs, is let out through several circular apertures in front of the vat, which can be narrowed or widened at pleasure, by means of a sliding plate. These apertures admit the pulp into a trough, which has a low side, or lip, and over the edge of this it flows, in a continued cascade, or even sheet: this trough of the vat is placed at one end of the machine, so that the stream of pulp falls upon a wire-cloth, or web, of many yards in length, the ends of which being united together, it is extended horizontally, in the manner of a jack towel, over two rollers, one of them placed close under the lip, or mouth of the vat, so that the stream of pulp descends as little as possible. The wire is kept supported by several other parallel rollers, that it may not hang down or bag, but be kept as level as possible, and by a very ingenious contrivance is kept extended in breadth to a proper tension; it therefore represents a table of several yards in length, which, by the revolution of the rollers, is kept in continual motion from the vat towards the end of the machine. The pulp is kept within bounds upon this table, according to the width intended to be given to the paper, by two pieces or rulers of wood, exactly parallel with each other, and also with the line of motion of the wire. Between the wire itself and these rulers are placed two endless straps of leather, as wide as the rulers, and revolving with the same velocity as the wire, but over different rollers. Similar rulers, and endless straps, are also placed in contact with the lower surface of the wire, so that the wire is confined between them on each side, and the liquid pulp thus prevented from running off on the sides, and they act as deckles to the mould. As they move together, they occasion no friction to destroy the wire. Near that part of the wire upon which the pulp falls from the lip in the vat, there is placed a flap of oiled silk, or other material, to prevent the pulp from running back towards the vat over the roller of the wire.

As the wire revolves upon its rollers, and carries the pulp along upon its surface from the vat to the other extremity, it is conducted between two rollers, fitted up in the manner of a rolling mill, which cause a pressure upon the pulp and paper to force out the water, and are therefore called the wet-press. In order to guard the pulp, which before passing between the rollers is in a soft state, from being dislodged, or otherwise injured by the upper roller coming immediately in contact with it; a revolving endless web of felt is applied. This is made of the same width as the endless wire, but not so long, and it is extended, like that, upon rollers situated above the wires; it is likewise brought between the rollers of the wet-press, so that its under surface falls upon the surface of the pulp, or paper, and defends it from the action of the upper cylinder: the wire and the felt are thus brought into contact with the paper between them, and the required pressure is given by means of screws, which increase or diminish the distance of the large compressing rollers, and these being covered with flannel cloth, or felt-ing, are prevented from injuring the wire webbing, as well as producing a better effect upon the paper than naked cylinders would do.

To prevent the water thus pressed out of the pulp from running back upon the paper, the wire is not only made to descend before it passes the wet-press, but there is also placed a small roller resting upon the wire, as near the press as possible, and some part of the water is previously got rid of, by both the wire and felt, with the pulp between them, passing through a small pair of rollers, to the axis of the upper one of which rollers are hung weights, in order to give a slight pressure. The water that drains from the pulp is collected into a trough, and returned to the vat by means of a scoop-wheel instead of a pump, which might form the paper stuff into lumps or rolls, by the mutual friction or rubbing of any parts of the apparatus against each other, and the reason for returning the water into the vat is to prevent the loss of a considerable portion of the paper. stuff, blue, size, &c. which would otherwise be sustained by its running to waste.

It is evident then, that if motion is given in the proper direction to the wet-press cylinders, having both the web and wire thus compressed between them, they will be drawn along by them, and caused to revolve upon their respective rollers; and that, as long as these webs continue so to revolve, and the pulp continues supplied and running upon the surface of the under web, so long will the machine continue making a sheet of paper, of continually increasing length. But as the paper, even after having passed between the rollers of the wet-press, is not of that consistency and strength as would allow of its being removed from the machine and cut in sheets, the new-made paper is caused to detach itself from the wire, at the moment it comes to the extreme roller, over which the wire revolves, and is immediately received upon a second web of felt, which is, like the former, stretched by two principal rollers and other subordinate ones. By the revolution of this web, which must have the same velocity as the former, the paper is brought between two rollers of brass or other hard metal, which are turned perfectly smooth, and placed some distance from the wet-press cylinders, but exactly parallel to them, and after passing through them the paper is received and wound upon a reel, or roller, which is from time to time removed, and others applied in their room as they are filled with paper.

This is the general action of the machine, but there are a number of very ingenious movements, which we have not mentioned. The shaking movement of the mould, which is so necessary to make the pulp coagulate into paper, is, in this machine, given to the wire thus: the frame of the roller on which the wire is extended at the end near the vat, is so placed on the top of upright legs, which are moveable on centres, as to admit the roller and wire with the deckle straps to move sideways a small quantity, and to return, in the manner of vibration, by the action of a crank. The number of these vibrations, or shakes, necessary in a given time, and the space passed through by the wire in each, will vary according to the quality and preparation of the pulp. The number, however, seems, by observation, to be limited to one or two hundred *per* minute, and the space between a quarter of an inch, and an inch. To enable the paper-maker readily to give a proper velocity to the crank according to his judgment, the same is turned by a small independent water-wheel, the velocity of which, and consequent number of vibrations, are regulated, at pleasure, by the quantity of water admitted upon the wheel. The sliding plate in the vat, which admits the pulp to flow out as first mentioned, is regulated by a screw, by which the circular aperture may be opened or shut in any intermediate degree, so that the quantity of pulp required to run from the

The excise duties on paper are subject, like other impositions of the same kind, to successive variation, both in their amount and rate; and so are likewise the bounties and drawbacks. And as, in the course of a few years, the enumeration of them would not only be useless, but erroneous, we shall content ourselves with observing, in general, that the principal act by which duties of excise are now collected, is the 43 Geo. III. c. 69; that by the 43 Geo. III. c. 81. more duties were added to those imposed by the former act, and by other subsequent statutes other duties increase the whole amount; and the particulars may be found in the schedules annexed to the several acts. We shall here subjoin some more permanent regulations.

Paper which hath paid the duty may be exported, and also books; and drawbacks are to be allowed subject to the regulations prescribed in several acts. (26 Geo. III. c. 78. 34 Geo. III. c. 20. 43 Geo. III. c. 69. sched. G.) The officer attending the packing of paper for exportation, shall take off the stamps from each ream or bundle, and any person obstructing him in this service shall incur a forfeiture of 50*l*. (26 Geo. III. c. 77.) By 49 Geo. III. c. 98. certain duties of customs are also payable upon papers; but old rags, old ropes or junks, or old fishing nets, may be imported duty free. (11 Geo. I. c. 7.) By 32 Geo. III. c. 54. Officers of the customs shall cause any printed, painted, or stained paper that is imported to be marked; and counterfeiting or forging the mark or number, subjects to a forfeiture of 100*l*.; and counterfeiting or forging any stamp or seal for making the impression, incurs a forfeiture of 500*l*.; and any person who shall sell paper with such counterfeit stamp, knowing the same, shall forfeit 50*l*. By 34 Geo. III. c. 20. the importation of books for sale, first printed in this kingdom, and reprinted in any other, incurs forfeiture of the same, and also 10*l*., and double the value of such book; provided this shall not extend to any book that has not been printed or reprinted in this kingdom, within twenty years before the same shall be imported, &c.

Every maker of paper or pasteboard, and every paper-stainer, shall take out a license from the office of excise, annually, for which he shall pay 2*l*., on pain of forfeiting 20*l*. (24 Geo. III. c. 41. 43 Geo. III. c. 69. sched. A.) All brown paper, made of old ropes, or cordage only, without separating or extracting the pitch or tar from them, and without any mixture of other materials, shall be deemed paper of the second class or denomination, and be chargeable with the duty accordingly; and all other paper whatever (glazed paper for clothiers and hot-pressers excepted) shall be deemed to be of the first class or denomination. (42 Geo. III. c. 94.) No paper shall be painted or stained for hangings, except that for which the duty on paper of the first class hath been charged, duly stamped, &c. (41 Geo. III. c. 8.) Nor is the maker to diminish any paper before it be charged, under the penalty of 50*l*. and also such paper. Pasteboard is to be made of paper charged, and unused for any other purpose, on pain of 100*l*., together with forfeiture of the same, and utensils, &c. employed in making it. (42 Geo. III. c. 94.) By the same act, the maker of pasteboard shall produce to the officers all such paper as he intends to use for pasteboard, duly wrapped and stamped, after 24 hours' previous notice, on pain of 100*l*.: nor shall any maker of pasteboard be a paper-maker, nor manufacture within a quarter of a mile of a paper manufactory, on pain of 100*l*. Places of making or keeping paper, pasteboard, mill-board, scale-board, or glazed paper, all utensils and materials employed, shall be entered, on pain of forfeiture, and also of 50*l*. (34 Geo. III. c. 20.) All paper shall be made up into quires, each quire consisting of 24 sheets, and

such quires shall be made up into reams of 20 quires each; and all pasteboard, &c. shall be made up in parcels, each parcel containing even dozens of sheets, of one and the same denomination, and of equal dimensions, and not less than 24, nor more than 72 such sheets in every parcel; tied up, &c. in wrappers, and marked with the class of paper to which it belongs, the number of the reams made by the maker during the current quarter, &c. &c. on penalty of 200*l*. and forfeiture. (42 Geo. III. c. 94.) Every maker may make his paper into quires without folding, provided that such quires, when made up into reams, be separated by a slip of coloured paper placed between each quire, and visible on the outside of the ream, and that the outside quires of each ream consist of not less than 20, nor more than 24 sheets, at the option of the maker. Every maker, whose mill or workhouse is situated in any city or market-town, who shall have any paper, paste-board, &c. to be weighed, and charged with the duty, shall give 24 hours (elsewhere 48 hours) previous notice, in writing, to the officer of excise, who shall attend, and such maker, or his servant, shall produce to the officer all such paper, pasteboard, &c. duly tied up, that the duty may be charged previous to removal; stamps shall be provided by the commissioners of excise; and if any person shall counterfeit such stamps, and sell with such counterfeits, knowingly, he shall forfeit 500*l*. (34 Geo. III. c. 20.), but this penalty is repealed, and the person committing the offence is adjudged guilty of felony, and subjected to transportation, as a felon, for seven years. 47 Geo. III. sess. 2. c. 30.

Paper-makers are enjoined to give notice to the proper officers of their names, places of abode, store-houses, &c. and to make regular entries, on oath, every six weeks, of all paper, &c. made by them, on penalty of 50*l*. and the duty shall be paid in six weeks after entry, on pain of double duty. 34 Geo. III. c. 20.

Paper-makers are forbid to remove or to conceal their paper, &c. till the officer has taken account thereof, on penalty of 50*l*., and forfeiture of the paper, &c. (24 Geo. III. c. 18. 34 Geo. III. c. 20. 42 Geo. III. c. 94.) Nor shall paper, &c. be removed in less than 24 hours, under the same penalty; nevertheless it may be removed from one mill to another, upon giving 48 hours' notice, in writing, to the officer. Paper that has been stamped and charged, is to be kept separate from other paper, and also paper of one class from that of another, on pain of 50*l*.

Persons molesting officers in the execution of this act (34 Geo. III. c. 20.) incur a penalty of 100*l*. and the penalties and forfeitures shall be appropriated, one moiety to the king, and the other moiety to the informer.

There is a drawback of the duties on paper exported; and also for books printed at Oxford or Cambridge, in the Latin, Greek, Oriental or Northern languages, and also for bibles, testaments, psalm-books, or books of common prayer, printed either in those universities, or by the king's printer, under certain conditions. 43 Geo. III. c. 69. sched. C.

Pasteboard, made of paper that hath paid the duty, shall not be charged with farther duty. (34 Geo. III. c. 20. 42 Geo. III. c. 94.) Allowance shall be made on paper damaged, for which the duty hath been paid; upon seven days' notice: and allowance shall be made to clothiers and hot-pressers; on certain conditions. 42 Geo. III. c. 94. 43 Geo. III. c. 69.

Stained paper (besides the duty paid for the paper before staining) is subject, by the former acts, to a duty of 1*½*d. a yard square. 43 Geo. III. c. 69.

Papers are of various kinds. With regard to colours,

they may be divided into *white, brown, blue, &c.* With regard to quality, into *fine, second, bastard, superfine, &c.* With regard to use, into *writing, printing, pressing, cap, cartridge, copy, chancery, post, &c.* With regard to dimensions, into *demij, medium, fool's-cap, pot, royal, super-royal, imperial, elephant, atlas, &c.* With regard to country, into *German, Lombard, Rochelle, Genoa, Holland, &c.*

French paper is divided into *large, middle, and small.* To the small belong those called *petit Romaine, petit Raisin, or Bâton royal, petit nom de Jesus,* and *petit à la main,* all thus denominated from the marks impressed on them in making. Also the *cartier,* for the backs of playing cards; *pot* for the figure side; *couronne,* which has commonly the arms of the comptroller-general of the finances; *tellere,* with the arms of the late chancellor Tellier, and a double T; and *chamfy,* or *à chassis la serpente,* so called from its mark, the serpent; which being extremely fine and thin, is used by fan-makers.

To the middling sort belong the *grand raisin simple, carré simple, cavalier,* and *lombard.* the three last of which are for printing; *l'écu,* or *de compte simple, carré double, l'écu double, grand raisin double,* and *couronne double,* which three last are denominated *double* on account of their strength and thickness. Add to these the *pantalon,* or paper with the Dutch arms; and *grand cornet,* so denominated from the impression on it.

To the larger belong the *grand Jesus, petit et grand fleur-de-lis, chapelet, colombier, grand aigle, dauphin, soleil,* and *l'étoile,* which are thus called from the figures they bear, being all proper for printing either at the letter-press or rolling-press; also for merchants books, and for drawing on. The *grand monde* is the largest of all. Vide Savar. D. de Comm. tom. ii. p. 965, seq.

We have also *printed paper,* for hanging rooms. (See PAPER-hangings.) *Stamped paper,* to write obligations, deeds, and contracts upon. (See STAMP.) *Ruled paper,* for books of accounts, &c. To which may be added *cut paper,* and *gilt paper,* for letters, &c. See GILDING of Paper.

PAPER, *Blue,* is a sort used by tradesmen to wrap up goods; as sugar-loaves, pieces of linen, &c.

PAPER, *Blotting,* is paper not sized, and in which therefore ink readily sinks or spreads. It is used in books of account, &c. in lieu of sand, to prevent blotting and disfiguring the opposite pages. The same kind is likewise used by apothecaries in filtrating juices, and other matters, for which the *manica Hippocratis* is not so proper.

PAPER, *Tint,* or *demi-tint,* for designing on, is either *brown, blue, or bistre.*

PAPER, *Bistred,* is white paper washed over with a sponge dipped in foot-water. Its use is to save the labour of the crayon, in places which are to be shadowed the same depth with the tint of this paper. For light places, they are made thereon with white chalk. Vide Corneil. Elem. de la Peint. Prat. cap. 15. p. 35. seq.

PAPER, *Marbled,* is a sort of paper variously stained, or painted as it were with divers colours; made by applying a sheet on the surface of a liquor wherein colours diluted with oil or ox's gall are suspended.

The manner of making it is thus: a trough is provided of the shape and dimensions of a sheet of the paper to be marbled, and about four fingers deep: this is made of lead or wood well joined, and pitched or primed to contain the liquor. For the liquor, a quarter of a pound of gum tragacanth is macerated four or five days in fair water; this they stir from time to time, and add to it daily fresh water, till it be of a consistency somewhat thinner than oil; then they strain it into the trough.

The colours to be applied thereon, for blue, are indigo ground up with white lead, or Prussian blue and verditer may be used: for green, indigo and orpiment, the one ground and the other tempered, mixed and boiled together with common water; or verdigris, a mixture of Dutch pink and Prussian blue, or verditer, in different proportions: for yellow, orpiment bruised and tempered; or Dutch pink and yellow ochre: for red, the finest lake, ground with raspings of Brasil wood, which has been prepared by boiling half a day; or carmine, rose pink, vermilion, and red-lead; the two latter of which should be mixed with rose pink or lake, to bring them to a softer cast: for orange, orange lake, or a mixture of vermilion, or red-lead, with Dutch pink: for purple, rose pink and Prussian blue. Into all these colours, properly ground with spirit of wine, they put a little ox or fish gall, which is two or three days old; and if the colours dilate not of themselves sufficiently, they add more gall: on the contrary, if they spread too much, the gall is over-dosed, and must be corrected by adding more of the colour without gall.

For the operation of marbling, when the gun is well settled in the trough, they extend a sheet of paper, and plunge it very shallow into the liquor, suddenly lifting it out again, in order to stir up, and raise the subsiding gum towards the surface, and for the more universal impregnating of the liquor.

This done, and all the colours ranged in gallipots on the table, where also the trough is placed, they begin by dipping a brush of hog's hair into any colour, commonly the blue first, and sprinkle it on the surface of the liquor: if the colour has been rightly prepared, it will dilate itself duly therein. This done, the red is applied in the like manner, but with another pencil: after this the yellow: lastly the green. For white, it is made by only sprinkling fair water, mixed with ox's gall, over the liquor.

When all the colours are thus floating on the liquor, to give them that agreeable cambletting, which we admire in marble paper, they use a pointed stick; which being applied by drawing it from one side of the trough to the other, with address, stirs up the liquor and fluctuating colours; then with a comb, made of wood, about five inches long, with brass teeth, about two inches in length, and a quarter of an inch distant from each other, taken by the head with both hands, they comb the surface of the liquor in the trough, from one extreme to another, permitting only the teeth to enter: this being performed with a gentle and uniform motion, makes those clouds and undulations on which the beauty of the paper depends.

If it be farther desired to have the colours lie in any other fantastical posture, representing serpents, or the like, it is effected with the pointed stick above-mentioned, by drawing it over what has been already combed; but this must be done with a dextrous hand, and with a shallow dip into the liquor, circling, as if you would draw some flourish, or figured letter.

Lastly, the colours being in this posture, the operator displays and applies on them a sheet of white moistened paper; to do which, artist-like, requires a sleight only to be obtained by practice; because the surfaces of the liquor and the paper are to meet equally in all parts; which done, before the colours have time to soak through, which, unless the paper be very thick, will be in the space of two or three pulses, he lifts up the paper nimbly, and with an even hand; and then, after spreading it a while on a board, hangs it on a line to dry; which, when sufficiently done, they first rub it with a little soap, and then polish it with a marble

stone, ivory knob, or glass polishers; or with a burnisher of jasper or agate.

It must be observed, that the sprinkling of the colours is to be renewed, and all the other ceremonies performed with the stick and comb, at every application of fresh paper, by reason that every paper takes off all the colour from the liquor. Vide Kirch. de Luce & Umbra, lib. x. par. 2. cap. 4. Merr. Observ. on Neri de Art. Vitr. cap. 42. p. 312. Hought. Collect. tom. ii. p. 419, seq.

Some attempts have been made to enrich the marbling, by mixing gold and silver with the colours; which succeeded well in many attempts in the French king's library, though the expence has hindered the practice from obtaining. Savar. ubi supra.

Mr. Boyle tells us, that paper, besides its common uses, may be made into frames for pictures, fine embossed work, and other parts of furniture. For this purpose, a convenient quantity of the best white sort may be steeped for two or three days in water, till it becomes very soft; then reducing it by the mortar and hot water into a thin pulp, it is laid on a sieve to draw off its superfluous moisture; then putting it into warm water, wherein a considerable quantity of fresh glue, or common size, has been dissolved, it may afterwards be put into moulds to acquire the designed figure; and when taken out may be strengthened, as occasion requires, with plaster, or moistened chalk, and when dry painted or overlaid.

This hint is since improved into a regular manufacture, under the name of *papier maché*.

Another use of paper is to stop up cracks or fissures in wooden vessels to hold water; for, in this case, it will forcibly dilate, and fill the place in which it is to lodge.

PAPER, *Chinese*, is of various sorts; some is made of the rinds or barks of trees, especially those abounding in sap, as the mulberry-tree and elm, but chiefly of the bamboo and cotton-tree; but, in reality, almost each province has its peculiar paper; that of Se-tchuen is made of hemp; that of Fok-kiang, of soft bamboo; that used in the northern provinces, of the bark of the mulberry-tree; that of the province of Che-kiang, of wheat or rice-straw; that of the province of Kiang-nang, of the skin found in the silk-worms balls; in sine, in the province of Hu-quang, the tre-chu, or ko-chu, furnishes the principal material for paper.

As to PAPERS made of the barks of trees; the manner of their preparation may be exemplified in the instance of that of the bamboo, a tree of the cane or reed kind, being hollow, and divided into joints; but much larger, smoother, harder, and stronger, than any other sort of reed.

For this paper, they ordinarily only use the second coat or skin of the bark, which is soft and white; this they beat in fair water to a pulp, which they take up in very large moulds or frames, so that they have sheets ten or twelve feet long, and sometimes more. They are completed by dipping them sheet by sheet in alum-water, which serves instead of the size used among us; and not only hinders the paper from too freely imbibing the ink, but gives it that lustre which at first sight makes it look silvered, or at least varnished over.

The paper thus made is white, soft, and close, without the least roughness to stop the motion of the pen, or occasion the rising of any of its fibres; though being made of the bark of a tree, it cracks more easily than the European paper: add that it is more apt to take moisture, that the duit sticks to it; and that the worms soon get into it; to prevent which last inconvenience, they are obliged often to beat their books and expose them to the sun. Add, that its thinness making it liable to be soon worn out, the Chinese

are under a frequent necessity of renewing their books, by fresh impressions taken from their blocks. Vide Le Compt. Nouv. Mem. sur Chin. lett. 7. Kust. Bibl. Nov. Libr. an. 1697, p. 67, seq. Leit. Edif. & Cur. tom. xix. p. 479.

But the paper of the bamboo, it is to be observed, is neither the best, nor the most used, in China. In the former of these respects, it yields the priority to the paper made of the cotton-shrub, which is the whitest and finest, and at the same time least subject to the inconveniences above-mentioned; because it keeps as well, and is as durable, as the European paper.

Dr. Grew thinks we may have plants in England, which contain a down that in all probability would make as fine a paper as that made by the Chinese, from their cotton-shrub. By which it appears he mistakenly imagined that the Chinese paper was made not from the rind of the cotton-shrub, but from the down or cotton itself. Vide Grew Mus. Reg. Soc. par. ii. sect. i. cap. 5. p. 215.

But the paper in most common use in China, is that made of the tree called *chu-ku*, or *ku-chu*, which Du Halde compares, first, to a mulberry-tree, then to a fig-tree, then to a sycamore tree, and lastly, to increase the embarrassment, to a strawberry-tree. By all which, we know no more of it than if he had said nothing about it.

The method of preparing it for paper, is by first scraping off lightly the thin outside of the tree, which is greenish: then they take off the inner rind in long thin slips, which they blanch in water, and in the sun; and afterwards prepare them in the same manner as the bamboo. It must not be forgot, that in the other trees it is only the inward bark that serves for making paper; but the bamboo, as well as the cotton-shrub, have this peculiarity, that not only their bark, but their whole substance, may be employed, by means of the following preparations.

Out of a wood of the largest bamboos, they select shoots of a year's growth, which are about the thickness of the calf of a man's leg: these they strip of their first green rind, and split them into straight pieces of six or seven feet long: the pieces thus cleft, they steep in a pond of muddy water, till they rot and grow soft by the maceration. In a fortnight they take them out, wash them in clean water, spread them in a large dry ditch, and cover them with lime for a few days; then they take them out again, and having washed them a second time, they slip them into small filaments, which they expose in the sun to dry and whiten: they throw them into large coppers, where they are thoroughly boiled: and lastly, reduce them by the strokes of large hammers to a thin paste or pulp.

After this, they take some shoots of a plant called *ko-teng*; they soak them four or five days in water, till there come out an unctuous fizy sort of juice; this they mix with the pulp of which the paper is to be made, somewhat in the same manner as painters temper their colours; care being taken not to put in too much, nor too little of it; on which the goodness of the paper much depends.

When they have mixed the juice of *ko-teng* with the cleft bamboo, and beaten the whole till it resembles a thick clammy water, they pour it into a large deep reservoir, consisting of four walls, raised breast high, and having the sides and bottom so cemented, that the liquor cannot run out, nor soak in.

This being done, and the workmen placed at the sides of the reservoir, they dip in their moulds, and take up the surface of the liquor, which almost instantly becomes paper; the mucilaginous and gluey juice of the *ko-teng* binding the parts, and rendering the paper compact, soft, and glossy,

but detached parts, and consequently is unfit for all designs where running work, scrolls, or other more complicated ornaments are introduced; it is extremely confined, with respect to the nature of the designs for which it can be employed; and the print is therefore most generally preferred. The method of laying on the flock by means of a print is this: a wooden print being cut (see *PAPER-hangings*) in such manner, that the part of the design, which is intended for the flock, may project beyond the rest of the surface, the varnish is put on a block covered with leather, or oil-cloth, and the print is then used to lay the varnish on all the parts where the flock is to be fixed. The sheet, thus prepared by the varnished impression, is now to be removed to another block or table; and to be strewn over with flock: which is afterwards to be gently compressed by a board, or some other flat body, to make the varnish take the better hold of it. Then the sheet is to be hung on a frame till the varnish be perfectly dry; at which time the superfluous part of the flock is to be brushed off by a soft camel's-hair brush, and the proper flock will be found to adhere in a very strong manner. When the stencil is used, the same method is to be pursued: the varnish for holding the flock being laid on by that instead of a print; and the flock afterwards strewn upon it, as in the other case.

The usual method of preparing the flock is, by cutting woollen rags, or pieces of cloth, with the hand, by means of a large bill or chopping-knife. But it is much more easily and better done by a machine; which may be worked by a horse-mill, at the same time such mill is employed for cutting diamonds, or any other similar purpose. In such case, the construction of that part of the machine, which is made for the cutting the flock, is this.

A box is made for containing the rags or cloth to be cut; which is open at the top; and of such size, as may best suit the quantity of rags that the force employed can cut. A blade is also to be made, the length of which is to be equal to the breadth of the box; and it should be strong; and must be charged with as great a weight as the force employed can be made to raise with a quick motion. The box being filled with the rags or cloth to be cut, is placed under the blade, and made to move by hitches, after the stroke of the blade is given, just so far as where it is proper the blade should again cut the cloth or rags; while, at the same time, the blade is lifted up, and let fall on the cloth, which it cuts through, till by successive strokes, and the progressive motion of the box under it, the whole quantity of cloth or rags in the box has been cut. The box must then be turned, so that one of the sides may become the front; and the operation must be repeated; by which means the cloth or rags, having been cut both ways, will be reduced to the state in which the matter is called flock; and fit to be employed for the purpose of paper-hangings. The work necessary for conveying from the principal mover in the mill, the motion for thrusting forward the box, and raising the blade, may be easily supplied by any ingenious wheelwright, and need not therefore be particularly described here.

There is a kind of counterfeit flock-paper, which, when well managed, has very much the same effect to the eye as the real: though done with less expence. The manner of making this sort is, by laying a ground of varnish on the paper; and having afterwards printed the design of the flock in varnish, in the same manner as for true; instead of the flock, some pigment, or dry colour, of the same hue with the flock required by the design, but somewhat of a darker shade, being well powdered, is strewn upon the printed varnish, and produces greatly the same appearance. Handmaid to the Arts, vol. ii. p. 458, &c.

PAPER-hangings are of several kinds; some of which are made in the representation of stucco-work, for covering ceilings, or the sides of halls, stair-cases, passages, &c. and others in imitation of velvet, damask, brocades, chintzes, or such silks and stuffs as are employed for hanging rooms.

The principal difference in the manufacture lies in the grounds; some of which are laid in varnish, and others in the common vehicles for water colours.

The kind of paper employed for this use is a sort of cartoon, manufactured for the purpose, which must be stamped before it be painted. 1 Geo. stat. 2. c. 36.

The colours proper to be used for painting paper-hangings are all those that can be used in water and varnish. But for common designs done with water only, the following are most proper.

For red, lake, vermilion, rose-pink, and red-ochre: for blue, Prussian blue, verditer, and indigo: for yellow, the yellow-berry wash, Dutch pink, and yellow ochre: for green, verdigris, or a mixture of the blue colours with the yellow colours, particularly with the yellow-berry wash: for orange, vermilion, or red lead, with Dutch pink: for purple, a wash made of logwood, or a mixture of the lake, or rose-pink, with deep coloured Prussian blue, or with indigo: for black, ivory black, and in some nicer cases lamp-black: for white, whiting: and for the heightings, white-lead.

Where great brightness is required, the lake should be used for the crimson red, and Prussian blue for the blue; but for many purposes, rose-pink used alone for the crimson red, and indigo mixt with whiting for the blue, will answer the purpose with greatly less expence. The lake, rose-pink, Prussian blue, and Dutch pink, intended for this use, should be procured in a moist state.

The colours used in varnish may be the same as those used in water; but for this purpose, those just mentioned should be obtained dry.

As for the vehicles of the colours; when water is used, it must be inspissated with size and gum Arabic or Senegal. When burnish is used, it must be formed of oil of turpentine, and the resins and gums which will dissolve in that menstruum. With respect to the grounds for paper hanging, those that are laid in water are made by mixing whiting with the size above mentioned, and laying it on the paper, with a proper brush, in the most even manner. Nothing more is necessary, when the ground is to be left white; and the paper being hung on a proper frame, till it be dry, is fit to be painted. When coloured grounds are wanted, the same method must be pursued; and the ground of whiting first laid; except that, in paler colours, a second coating may sometimes be spared, by mixing some strong colour with the whiting. But where a greater force of colour is wanted, the pigment or colouring substance must be tempered with the proper vehicle, and then spread over the white coat. The varnish grounds are made much in the same manner, by mixing the proper colour with the varnish, and spreading it on the paper.

There are three methods by which paper-hangings are painted: the first by printing on the colours; the second by using the stencil; and the third by laying them on with a pencil, as in other kinds of painting.

When the colours are laid on by printing, the impression is made by wooden prints; which are cut in such manner, that the figure to be expressed is made to project from the surface, by cutting away all the other part. This, being charged with the colours tempered with their proper vehicle, by letting the print gently down on a block, on which the colour is previously spread, conveys it from thence to the ground of the paper, on which it is made to fall more forcibly by means of its weight, and the effort of the arm of the

person who uses the print. The manner of doing this, when more particularly explained, is thus.

The paper being properly prepared by a ground of whitening, colour, or varnish, is laid on a proper block, on which a piece of leather is strained. The colour, mixed with its proper vehicle, is spread on another piece of leather, or oil cloth, laid on a flat block, somewhat larger than the print; which is done by a boy or man who attends for that purpose; and having the colour by him, in a pot, spreads it with a brush on the block betwixt every stroke and impression the printer makes. The print is previously cut in such manner, correspondently to the design of the painting, that there shall be a projection on the surface answering to every part, where that colour intended to be conveyed by this print is necessary. The printer then takes the print either in his right hand, or, when too heavy to be so managed, in both, and drops it gently on the block, just charged with colour; from whence he again immediately raises it in the most perpendicular direction, and lets it fall in the strongest, though most even manner, he can, on the paper; increasing the force by all the additional velocity he can give the print. When this is done, the sheet printed is immediately taken off the block, and hung up to dry; and another being put in its place, the same operation is repeated, till the whole quantity of paper be printed. It is easy to conclude, that there must be as many separate prints, as there are colours to be printed; and they are to be used successively in the same manner as the first. But where there are more than one, great care must be taken, after the first, to let the print fall exactly in the same part of the paper, as that which went before: otherwise the figure of the design would be brought into irregularity and confusion. In common paper of low price, it is usual, therefore, to print only the outlines, and lay on the rest of the colours by stencilling; which both saves the expence of cutting more prints; and can be practised by common workmen, not requiring the great care and dexterity necessary to the using of prints.

The manner of stencilling the colours is this. The figure, which all the parts of any particular colour make in the design to be painted, is to be cut out, in a piece of thin leather, or oil cloth. These pieces of leather, or oil cloth, are called stencils; and being laid flat on the sheets of paper to be printed, spread on a table or floor, are to be rubbed over with the colour, properly tempered, by means of a large brush. The colour passing over the whole is consequently spread on those parts of the paper where the cloth or leather is cut away, and give the same effect as if laid on by a print. This is nevertheless only practicable, without great care, in parts where there are only detached masses, or spots of colours: for where there are small continued lines, or parts that run one into another, it is difficult to preserve the connection or continuity of the parts of the cloth, or to keep the smaller corners close down to the paper; and therefore, in such cases, prints are preferable. Stencilling is indeed a cheaper method of ridding coarse work than printing; but without such extraordinary attention and trouble, as render it equally difficult with printing, it is far less beautiful and exact in the effect. For the outline of the spots of colour want that sharpness and regularity that are given by prints; besides the frequent extralineations, or deviations from the just figure, which happen by the original misplacing of the stencils, or the shifting the place of them during the operation.

Pencilling is only used in the case of nicer work, such as the better imitations of the India paper. It is performed in the same manner as other paintings in water, or varnish.

It is sometimes used only to fill the outlines already formed by printing; where the price of the colour, or the exactness of the manner in which it is required to be laid on, render the stencilling or printing it less proper: at other times it is used for forming or delineating some parts of the design, where a spirit of freedom and variety, not to be had in printed outlines, are desired to be had in the work.

The manner of proceeding with these several methods is, in common work, to stencil first all parts of the colour in the design, and to give an outline to the whole at last, by printing with brown or black: but where there is any running part of the designs, such as scrolls, or the stems or stalks of creeping plants, or flowers, which are to be printed in any other colour than brown or black, a print must be used for them; though, if they require only brown or black, they may be done by the same print which makes the outlines.

In the finer paper, where several colours are laid on with the prints, the principal colour is begun with; and the rest taken successively; the print for the outline being laid on last. In cases where the pencil is to be used, the outline is nevertheless to be made before the colours are laid on by the pencil, if such outline is to be made at all; because that is the guide to the person who lays on the colour; and confines them to a correctness.

In paper printed with designs in chiaro-scuro, such as the imitation of stucco work, and bas relievos, the order of printing must be, to lay on the ground colour first; afterwards the shades; and lastly the lights: and the same rule of succession must be observed where the colours are pencilled. Handmaid to the Arts, vol. ii. p. 445, &c.

Paper-hangings may be spangled with that kind of talc called isinglass, which being reduced to a gross flaky powder, has a great resemblance to thin silver scales or powder. It is laid on by strewing over the varnish, which forms the ground, before it begins to dry. When it is laid on in a figure, for the representation of embroidery, the figure must be printed in varnish, and the talc strewed upon it, and treated like flock. Smalt may also be used in the same manner as flock or spangles. But hangings of this kind are now little used.

PAPER, ruled for the reception of musical characters. Rousseau was the first, we believe, who made this a lexicographical article. Five parallel lines form what musicians call the *staff*; upon which lines in the spaces are disposed all the notes of the time-table and their places in the general scale, regulated by clefs at the beginning of each staff.

All our music for keyed instruments, till the latter end of the seventeenth century, was written on staves of six lines, of which the lowest in the treble clef, and highest in the base, was the middle C of the general scale. See *STAFF*.

Almost all the music paper in Italy is ten-staved, for the convenience of scoring songs with four instrumental parts: as the violino primo, violino secondo, alto viola, voice part, and base. These being linked together by braces, are easily found, not only by the fingers, but by the instrumental performers, by whom they may be accompanied from the score.

The English have paper ruled on all forms and number of staves. In general, for violins, of 12 staves, and for the piano forte, and vocal parts, long quarto, as it is more on a level with the eyes, and conceals the visage of the performers less from the audience.

PAPER, among *Bankers*, and other negociants, is also used for bills of exchange, bank and promissory notes, &c.

Substituting paper for money, and giving the paper an

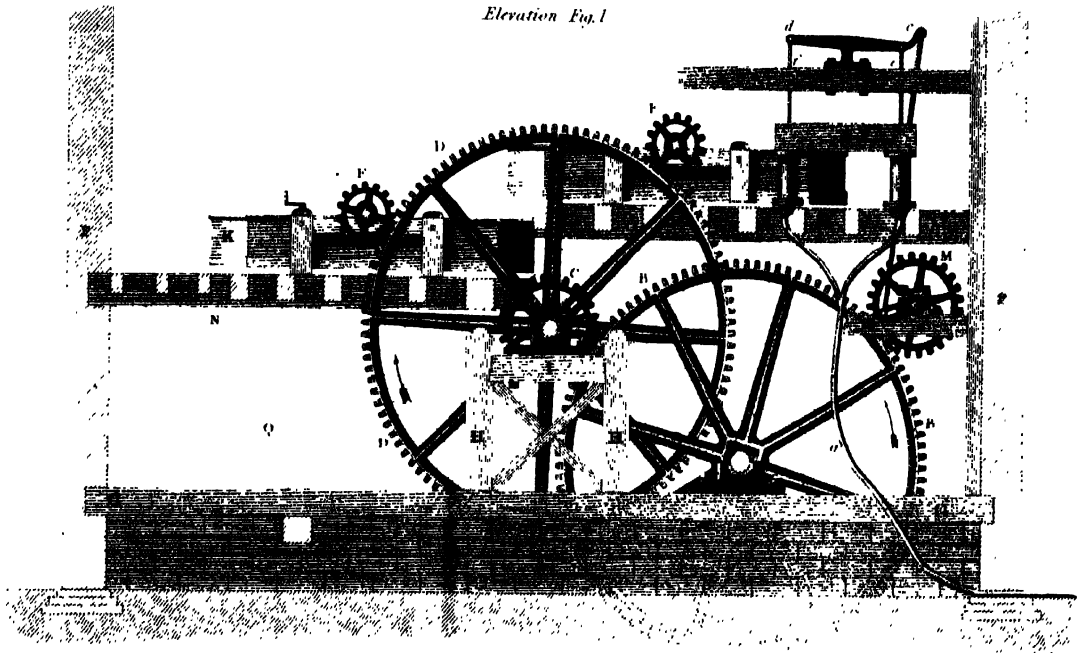
arbitrary value, was the way of paying debts introduced in France by Mr. Law. A royal bank was established, to which people were to carry their money, and receive the value of it in bills, which were to pass current in trade as so much money. (Vide Cheygn. Scienc. des Pers. de la Cour, tom. ii. p. 292.) It was made confiscation of goods, and the gallies, for any man to keep above forty livres by him

of any but paper money. When the regent was told what a rage was spirited up against him about the arrears of making paper current, and how openly the people threatened him, he answered coolly, the French were like watch-dogs, they would bark, but not bite : " Les François ressemblent aux chiens a garde, ils aboyent, mais ne mordent pas." Misc. Lett. tom. iv. p. 16.

PAPER MILL

PLATE 1.

Elevation Fig. 1



Plan, Fig. 2

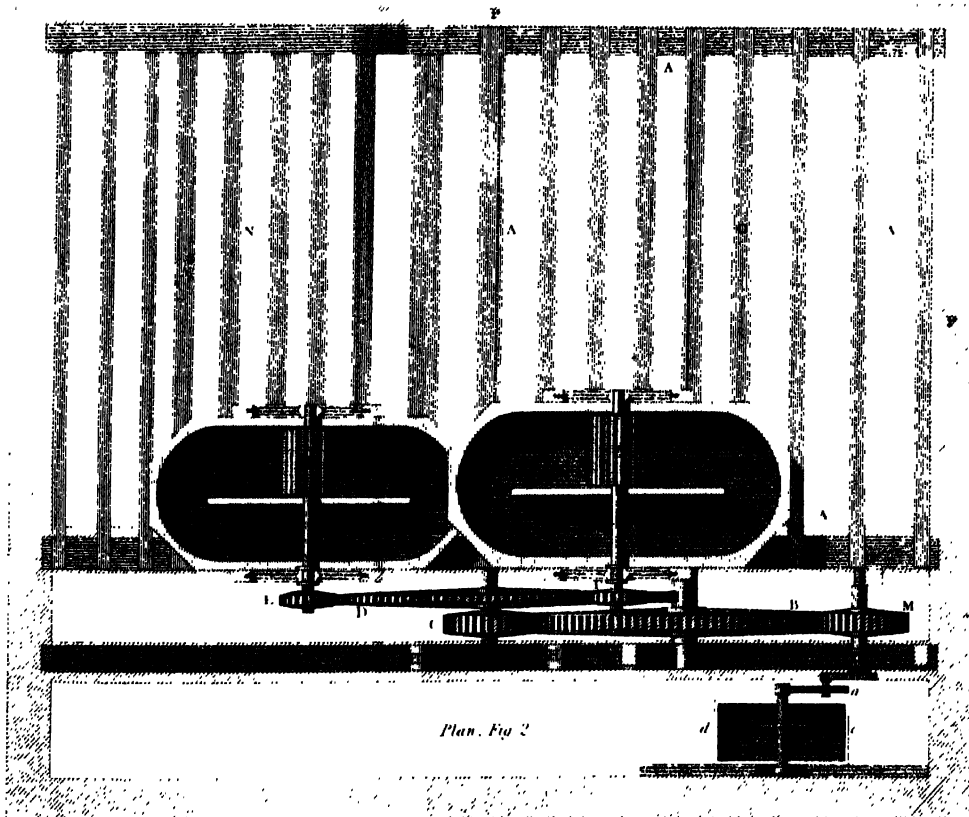


Fig. 5.

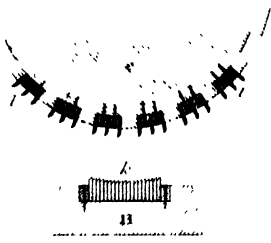


Fig. 1. Section of an Engine.

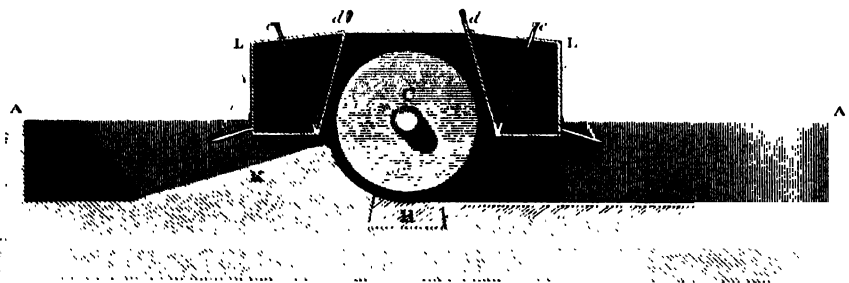
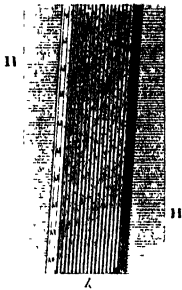


Fig. 4



Man

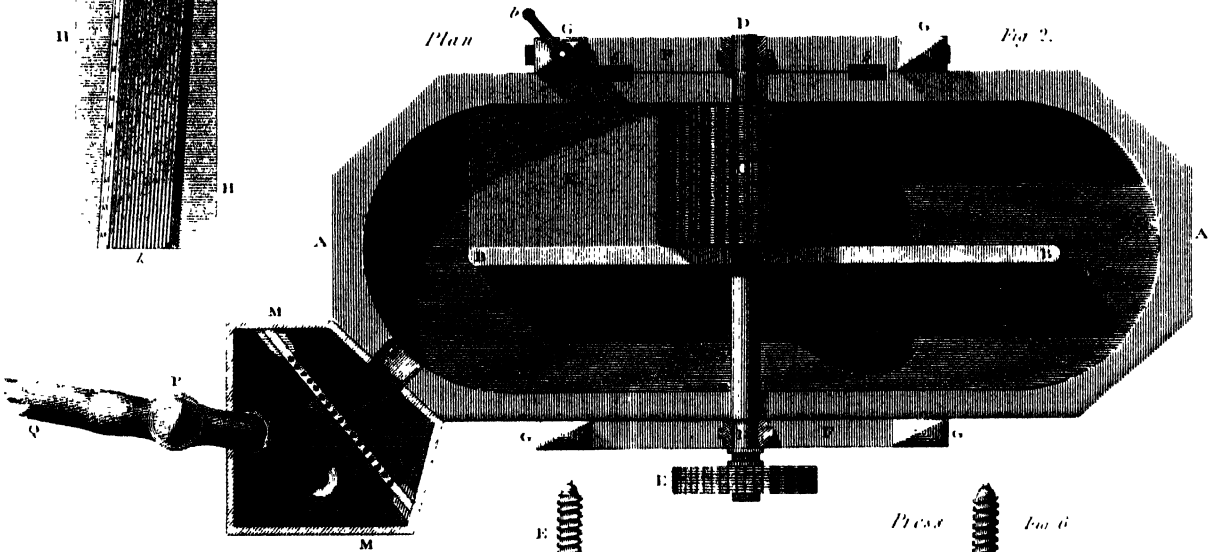


Fig. 2.

Phox  *Imi*

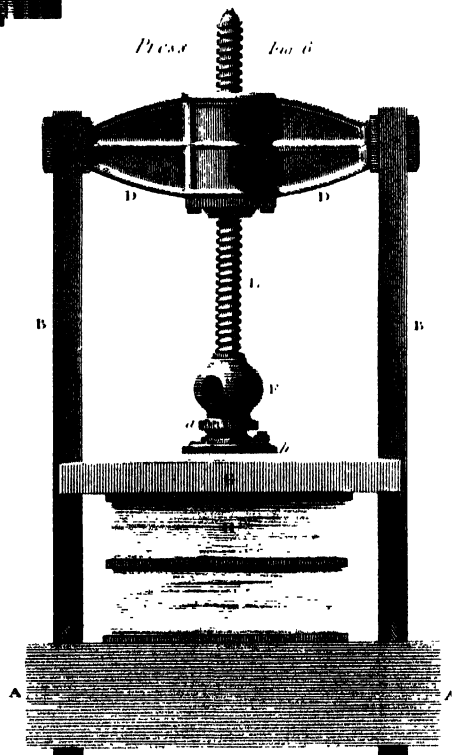
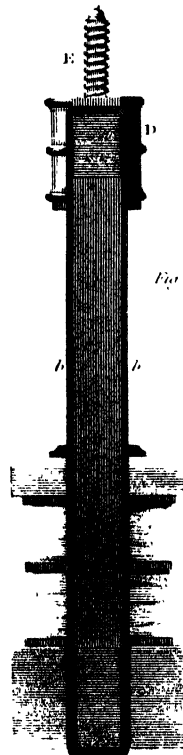
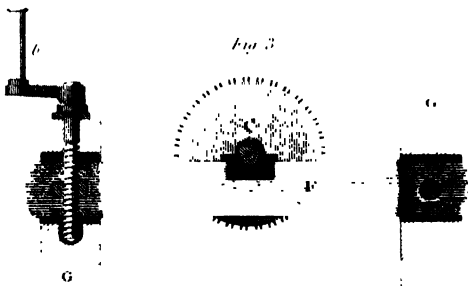


Fig. 7



by 3



Papin

PAPIN, DENYS, in *Biography*, an ingenious physician, the son of Nicholas Papin, also a physician, was born at Blois. He took the degree of doctor, and travelled to England, where he was elected a fellow of the Royal Society, in December 1680. He passed the following year in London, and published an account of a machine which he had invented, and which still bears his name; this was "The New Digester, or Engine for the softening of Bones," 4to. 1681. It soon appeared in French, with the title of "La Manière d'Amolir les Os, et de faire cuire toutes sortes de Viandes en peu de tems et à peu de fraix." Paris 1682. The machine consists of a very strong metal boiler, with an air-tight cover screwed down with great force; hence the contained matter, being incapable of escaping either by evaporation or by bursting the machine, may be heated to a degree far beyond that of boiling water, so as to dissolve the gluten of bones and cartilages. He afterwards improved this digester,

and it has since been much employed in chemical and philosophical experiments. He assisted Boyle in various experiments, of which an account is given in the history of the Royal Society. Papin was a Calvinist, and was therefore prevented from returning home by the revocation of the edict of Nantes. He afterwards resided at Marburg, where he taught the mathematics, and published a "Fasciculus Dissertationum de quibusdam Machinis Physicis," 12mo. 1696; and in 1707, he published at Francfort an account of a machine which he had invented for raising water by the action of fire, entitled "Ars nova ad aquam ignis adminiculo efficacissimè elevandam."

His father, Nicholas Papin, was author of several works, which, however, are nearly forgotten. Two of them related to the powder of Sympathy, which he defended; and one to the discovery of Harvey, which he opposed. Eloy Dict. Hist. de la Med. Gen. Biog.

Parallel motion

PARALLEL Motion, is a term used among practical mechanics to denote the rectilinear motion of a piston-rod, &c. in the direction of its length; and contrivances, by which such alternate rectilinear motions are converted into continuous rotatory ones, or *vice versa*; for pumps, steam-engines, saw-mills, &c. are usually called parallel motions, or parallel levers. In the modern improved steam-engines and pumps, close cylinders are generally used for the pistons to act in, which being worked by polished rods sliding through collars or stuffing-boxes in the lids of the cylinders, it has become necessary to contrive methods for causing the piston-rod to move accurately up and down in the same right line. The different combinations of levers used to produce this effect are worthy of our notice, as exhibiting some ingenious applications of geometrical principles. The object of the parallel motion is, to convert the motion of the end of a reciprocating beam or lever, into a vertical or rectilinear motion; or the continuous motion of a crank at once into a reciprocating motion.

The simplest and most obvious method of producing either of these effects, is to connect the end of the piston-rod to the beam, or the crank, by means of joints, with a connecting rod of a proper length between them, and confine the former, to preserve its rectilinear movement, by sliding through a collar, or in grooves. Friction-wheels may be used to make it work easily; but in machines which have great strains, the constant wear of the grooves or wheels would soon produce looseness, and destroy the parallelism of the motion: recourse must, therefore, be had to parallel levers.

Plate III. of Steam-engines. contains three different constructions of levers, which are in common use in steam-engines, to produce parallel motions. Two of them, *figs. 1, 2, 3, and 4,* were, we believe, first introduced by Messrs. Boulton and Watt, as appendages to their patent steam-engine, in lieu of the sectors, or arch heads with chains, formerly applied to the beams of the old atmosphere engines. The most simple of these two is represented in *figs. 3 and 4*, where the pump, or piston-rod *T*, is required to move always in the line *T T'*, when actuated by the beam, or lever, *H B*, whose centre of motion is *A*, and the point *I*, from which the rod receives its motion, of course moves in an arc of a circle. To this point, one end of a bar, or link *I K*, of any convenient length, is jointed, and to the opposite end, *K*, the extremity of a lever, *K L*, is attached by the joint or centre-pin *K*, the other end, *L*, moving on a fixed centre of motion. The lever, *K L*, is exactly equal in length to the acting radius, *A I*, of the beam, and its centre of motion, *L*, is attached to a fixed support, so situated, that when the beam, *A I*, is horizontal, or at right angles to the line *T T'*, the lever, *K L*, will also be horizontal, and therefore parallel to *A I*; at the same time the link, *I K*, which connects them, must hang perpendicular. A centre-pin is fixed at *M*, exactly in the middle of *I K*, and to this centre the top of the piston-rod, *T*, is attached. Now the effect of the combination is, that the point, *M*, will always move in the vertical line *T T'*,

when the beam or the point, *I*, describes an arc of a circle round the centre *A*; for it is evident, that when the levers, by the motion of the beam on its centre, are brought into the position shewn by the dotted lines *A, I, K, L*, (*fig. 3.*) either above or below the horizontal, the upper end of the link, *I K*, is drawn as much out of the line, *T T'*, on one side, by the curved motion, or sweep of the beam, as the lower end is drawn out of that line, on the opposite side, by the sweep of the lever *K L*; consequently, its middle point, *M*, continues always in that line, and prevents the piston-rod deviating from it. The movement may be readily traced by inspection of the diagram, *fig. 3*, which exhibits the levers in three different positions.

Figs. 1 and 2 represent another of Boulton and Watt's parallel motions, and is that now most commonly used by themselves and other engine-makers. This, as before described, has two fixed centres, *A* and *F*, and rods connected by moveable joints *C, B, D* and *E*, forming a parallelogram.

In setting out of these centres, the line *G G*, in which the piston is to move, should fall as much short of the end of the beam, or point *B*, when in the horizontal position, as it will be beyond the end of the same at the two extremes of the movement, which positions are represented by dotted lines, *fig. 1*: the link, *B D*, connects the end of the beam with the top of the piston-rod, and about half way to the centre of the beam, another link, *C E*, of the same length, is jointed, being always kept parallel to the former by a connecting rod, *D E*, which is equal in length to *C B*, so that *C B, D E*, may form a parallelogram, in whatever position it may be placed by the motion of the beam, and the consequent motion of the links and coupling-rod on their moveable centres.

The parallelism of the point, *D*, is produced by means of the lever, *E F*, which is connected to the point, *E*, of the parallelogram, and the other end moves on the fixed centre, *F*; therefore the end, *E*, of the rod, *E D*, moves in an arc of a circle, round the centre *F*; the other end, *D*, will be found to traverse the right line *G G*.

The proportions of the levers of this motion admit of great variation: the simplest case is, when the radius, *A C*, is exactly half of *A B*, then *E F* must be equal to *A C* or *C B*. Considerable latitude is allowed to the workman in the length of the links *B D* and *C E*, without sensibly deranging the parallelism of the point *D*, and piston-rod attached to it. With these proportions, the centre, *F*, will fall upon the line *G G*, which is often inconvenient; for as there are two of the parallelograms, *C E* and *D B*, one on each side of the beam, the centres of the lever, *E F*, cannot be made on one common axis. Eleven different proportions for these levers will appear by the following table of dimensions, in inches, taken from some of the best steam-engines, by various makers in or near the metropolis.

Figs. 1 and 2.	Length of Stroke D d.	Beam A B.	Coupling Rod, D E C B.	Link, C E = B D.	Bridle = Lever E F.
N ^o 1	96	147	69	42	78
2	72	120	50	28	96
3	72	110	55	31½	55
4	48	90	41	20	60
5	48	84	38	19	60
6	48	84	36	20	54
7	48	72	41	18	25
8	45.6	76	40	28	36
9	36	60	37	12	15.66
10	24	37	16	9	26
11	23	36	16	12	26

The principle on which parallel motion, or what is insensibly near to one, is produced in all these different cases, will best appear, after explaining a different construction for the same purpose by Mr. Freemantle.

Fig. 6. represents this parallel motion, which is effected by means of two fixed centres, D and E, and the three moveable ones B, C and A. In this case the beam-centre, A, is not stationary, but has a small motion on its support D A, which is moveable on the fixed centre D: the centre C, which unites the lever, E C, to the beam, is in the middle of the beam, (*i. e.* B C = C A, and E C is also of the same length,) the support, D A, being of any convenient length; but the longer the better, since the construction requires, in strictness, that the point, A, should slide horizontally in the dotted lines E, A, instead of descending in each end of its course in the arc of the radius D A. The piston-rod, G, is jointed immediately to the end of the beam at B. The parallelism of the motion in this contrivance is effected by the lever, E C, compelling the middle point of the beam, A B, to move upon the arc C C, as it librates upon its centre, whilst that point traverses upon the top of the bar, A D, to such an extent, that the extremity, B, will always traverse upon the line G G, and of course carry the piston-rod with it. This may be demonstrated thus: supposing E A to be a horizontal line, let the dotted line, B A, represent any position whatever of the beam, and E C the corresponding position of the lever; then B C E and A C E will form two isosceles triangles, because of the equal sides B C and C E, and E C and C A: their opposite angles are equal, as E B C = B E C, and C E A = C A E; and because the angle, B E A, is made up of the angles B E C and C E A, the same, (B E A,) is equal to the sum of the two angles, B and A, of the triangle B A E, which shew the third angle, E, to be a right angle; therefore the point, B, will be perpendicular over E, or perpendicular beneath it, as a similar construction, below the line E A, would shew. As the demonstration is equally true of every other part of the movement, as well as its extremes, the angle, B E A, will in all cases be a right angle, and consequently produce a parallel motion. We have here supposed the centre, A, to be confined to slide along the line E A; but in practice it has been found, that the point, A, may be allowed to move in the arc of a circle, described on the centre D, instead of the right line E A, without producing sensible deviation in the parallelism of the point B, and the piston-rod, G, attached to it. The fixed centre, E, may also be moved out of the line B B, either towards or from the centre A, within certain limits, making proportionate alteration in the lengths of the lever E C, and radius A C, as will be evident on making the fol-

lowing comparison between the constructions in fig. 2. and fig. 6. If in figs. 1. and 2. we produce the line D E, and from A draw a line parallel to C E and B D, intersecting it in Y, then suppose the figures turned upside down, and end for end, we can compare the fixed centre D, fig. 6, with A, fig. 2; and the fixed centre E, fig. 6, with F; also the beam A B, fig. 6, with the produced coupling rod Y D; the support D A, fig. 6, with A Y; and the lever E C, fig. 6, with F E: it will then appear that the two constructions are essentially the same in principle, supposing the fixed centre, E, moved out beyond the line B B, as has been mentioned above to be practicable.

The dimensions, given in our table above, will shew what considerable variations in the proportion of lengths, particularly with regard to the lever E F, fig. 2, may be made in practice, without sensibly impairing this admirable contrivance for producing a vertical motion from a power moving up and down, in the arc of a circle described by the end of the beam.

A very ingenious parallel motion is represented in fig. 5, which converts the rectilinear motion of a piston-rod at once to a rotatory motion for a crank or axis. This contrivance has been ascribed to an American, named White; and has been adopted in steam-engines by Mr. Murray, of Leeds. It is founded on a well-known property of epicycloidal curves, *viz.* that if within any given fixed circle another circle rolls round, which is just half the diameter of the fixed circle, any point in the circumference of the rolling circle describes a right line, which crosses the longer circle, as a diameter thereto. The mode of construction is easily understood from the figure, in which A B is a fixed circle, or hoop of cast iron, whose internal diameter is equal to the stroke of the piston; it is supported externally by standards G and H, and furnished with small teeth all round the interior part of its circumference; C is a toothed wheel, whose diameter is only half that of the ring; the axis of the wheel, which is to have the rotatory motion, passes through the centre of the ring, and has a circular iron plate, or wheel E, fixed upon the extremity of it; from this plate, a pin or bolt, R, projects, and is by the motion of the axis carried round in a circle, in the manner of a crank. This pin forms the centre-pin of the small wheel C, and therefore compels it to roll round within the great circle, and keep the teeth always in contact. The upper extremity of the piston-rod is attached to a pin, F, fixed on the circumference of the small wheel, at the point where the two wheels will be in contact, when at the lowest and highest points of the motion.

The pin F, at the circumference of the small wheel, is adjustable by a slider and screw, so as exactly to suit the diameter of the outer circle; and the piston-rod, being attached to it, is moved truly up and down in the line I K, in a very regular manner, when the axis of the plate, E, is turned round; or *vice versa*, if the impelling power is applied to the piston-rod, in which case a fly-wheel must be applied upon the central axis to regulate the motion.

The extremity of the piston-rod will be confined to move in the vertical diameter of the ring, because it is made to describe an epicycloid of that kind, which is formed by a circle rolling round within the inside of another circle of double diameter, in which case, it is well known the epicycloid becomes a diameter of the larger circle, and the smaller circle makes two complete revolutions, while it is revolving from any one point of the larger circle to the same point again.

In all the motions we have described, the conversion of the reciprocating motion to a rotative, is effected by means

of a crank, which communicates with the beam by a connecting rod at the opposite end of the beam, in the manner of H K, *fig. 4*; usually at the end opposite to the parallel levers. Some mechanics have supposed it desirable, in a parallel motion, to give the piston-rod, the saw, or the like, an uniform velocity through the whole of its progress; then to bring it at once to rest again, and to give it instantaneously its intended velocity in the opposite direction, and so on. This the crank will not do, as its motion, at the point where the change or reciprocation of motion takes place, is imperceptible; they have therefore sought other means.

One method of producing this effect is, to make the piston-rod consist of two parallel bars, having teeth in the side, which front each other. Let a toothed wheel be placed between them, having only the half of its circumference furnished with teeth. It is evident, without any further description, that if this wheel be turned uniformly round its axis, the piston-rod will be moved uniformly up and down without intermission. This has often been put in practice, and the piston-rod made to work between grooved rollers, but the machine always went by jolts and seldom lasted a few days. Unskilful mechanics attributed this to defects in the execution,

but the fault is essential, and lies in the principle. The machine could not perform a single stroke without breaking, if the first mover did not slacken a little, or the different parts of the machine did not yield by bending, or by compression, and no strength of materials could withstand the violence of the strains at every reciprocation of the motion. This is chiefly experienced in great works, which are put in motion by a water-wheel, or some other equal power, exerted on the mass of matter of which the machine consists. The water-wheel, being of great weight, moves with considerable steadiness, or uniformity; and when an additional resistance is opposed to it by the beginning of a new stroke of the piston, its great quantity of motion is but little affected by this addition, and it proceeds with very little loss of motion. The machine must either yield a little by bending, and compression, or go to pieces, which is the common event. Cranks are free from this inconvenience, because they accelerate the piston gradually, and bring it gradually to rest, while the water-wheel moves round with almost perfect uniformity. The only inconvenience attending this slow motion of a piston at the beginning of its stroke, is, that the valves do not shut with rapidity, so that some water gets back through them. But when they are properly formed and loaded, this is but trifling.

Parchment

PARCHMENT, in *Commerce*, &c. sheep or goats' skin prepared after a peculiar manner, which renders it proper for several uses; particularly for writing on, and for the covering of books, &c.

The word comes from the Latin *Pergamena*, the ancient name of this manufacture; which it is said to have taken from the city of Pergamos, to Eumenes, king whereof, its invention is usually ascribed; though, in reality, that prince appears rather to have been the improver than the inventor of parchment; for the Persians of old, according to Diodorus, wrote all their records on skins; and the ancient Ionians, as we are told by Herodotus, made use of sheep-skins and goat-skins in writing, many ages before Eumenes's time. Nor need we doubt, that such skins were prepared and dressed for that purpose, after a manner not unlike that of our parchment, though, probably, not so artificially. Vide Diod. Sicul. lib. ii. p. 84. Herodot. lib. v. Prid. Connect. part i. lib. vii. p. 708.

Dr. Parleaux is a strenuous advocate for the antiquity of parchment; and he imagines that the authentic copy of the law which Hilkiah found in the Temple, and sent to king Josiah, was formed of this material; because no other used for writing, parchment excepted, could be of so durable a nature as to last from the time of Moses till that period, for eight hundred and thirty years. But it has been replied to this argument, that the Egyptians wrote on linen those things which they designed for long duration; and those who have examined mummies with attention, assure us, that the characters so written continue to this day. It is not, therefore, improbable, that a copy of the law of Moses, written after this manner, might have lasted eight hundred and thirty years. Besides, it is not very likely that those skins which were used, according to the testimony of Diodorus and Herodotus, by the Persians and Romans for writing, long before the time of Eumenes, were dressed like parchment. They must have been prepared in a much ruder manner, and have little resembled the parchment, of which Eumenes is said to be the inventor; because, if it had been found out before, it would have rendered the want of the Egyptian papyrus no inconvenience to that prince. Such skins might do for records, and for some occasional writings, but would have been by no means proper for books. Hence some writers have concluded, that parchment was a later invention than the Egyptian paper.

Parchment constitutes a very considerable article in the French commerce; it is made in most of their cities; and, besides the consumption at home, they send vast quantities abroad, particularly to England, Flanders, Holland, Spain, and Portugal.

That called *virgin* parchment is somewhat thinner and finer than the rest; and is most proper for certain purposes,

as fans, &c. and made of the skin of an abortive lamb, or kid.

PARCHMENT, Manufacture of. The skin having been stript of its wool, and having passed the lime-pit (after the manner described under the article SHAMMY), the skinner stretches it on a kind of frame, consisting of four pieces of wood, mortised into each other at the four angles, and perforated lengthways from distance to distance, with holes furnished with wooden pins, that may be turned at pleasure, like those of a violin.

To stretch the skin on this frame, they make little holes all around it, and through every two holes draw a little skewer; to this skewer they tie a small piece of pack-thread, and tie that over the pins; so that coming to turn the pins equally the skin is strained tight every way, like that of a drum.

The skin being thus sufficiently stretched on the frame, the flesh is pared off with a sharp instrument for that purpose; this done, it is moistened with a rag; and a kind of white stone, or chalk, reduced to a fine dust, is strewed over it: then, with a large pumice-stone, flat at bottom, much after the manner of a mullet for grinding colours, they rub over the skin as if about to grind the chalk; and thus they scour off the remains of the flesh. Then they go over it again with the iron instrument; again moisten it as before, and again rub it with the pumice-stone without any chalk underneath; this smoothenes and softens the flesh-side very considerably. They then drain it again, by passing over it the iron instrument as before.

The flesh-side being thus drained, they pass the iron on the wool or hair-side; then stretch it tight on the frame by means of the pins, and go over the flesh-side again with the iron; this finishes its draining; and the more the skin is drained, the whiter it always becomes.

They now throw on more chalk, sweeping it over with a piece of lamb-skin that has the wool on; this smoothenes it still farther, and gives it a white down or knap. It is now left to dry, and when dried it is taken off the frame, by cutting it all round.

The skin, thus far prepared by the skinner, is taken out of his hands by the parchment-maker, who first scrapes or pares it dry on the summer with an iron instrument like that above-mentioned, only finer and sharper; with this, worked with the arm from top to bottom of the skin, he takes away about one-half of its thickness. The skin, thus equally pared on both sides, they pass the pumice-stone over both sides, to smoothen it. This last preparation is performed on a kind of form or bench covered with a sack stuffed with flocks, and it leaves the parchment in a condition for writing on.

The paring of the skin dry on the summer is the most difficult preparation in the whole process of parchment-making; for which reason, the skimmers seldom dare meddle

with it, but usually leave it to those more experienced in it; the summer, whereon it is performed, is a calf-skin well-stretched on a frame, serving as a support to the skin, which is fastened a-top of it with a wooden instrument, that has a notch cut in it. Lastly, that the iron knife may pass the easier between the summer and the skin to be pared, they put another skin, which they call the counter-summer. The parings, thus taken off the skin, are used in making glue, tize, &c.

What we call *vellum*, is only parchment made of the skins of abortive calves, or, at least, of sucking calves; it is finer, whiter, and smoother, than the common parchment; but it is prepared in the same manner as that, except that it is not passed through the lime-pit.

PARCHMENT, To make a green transparent. Wash the parchment in cold ley, till it come clear from it; then squeeze out the liquor as much as possible; and if you would have it of a fine green colour, take distilled verdigris, ground with vinegar, and add a little sap-green to it; temper it neither too thick nor too thin; then soak your parchment in this colour thoroughly a whole night; rinse it afterwards in water, strain it immediately on a frame, and set it to dry; take clear varnish, lay it on both sides, set it in the sun to dry; after this cut the parchment out of the frame into leaves, as large as you please, and lay them in a book under press, to keep them fine and straight. The effect of this parchment is to make a small letter, when put over it, appear as big again; and it is a great preserver of the eyes, especially to those that read much by candle-light. The varnish must be prepared of linseed-oil, and boiled with frankincense, mastich, and sandarac.

If you would have the parchment of a clear, transparent, and white colour, only wash, strain, and varnish it, as above. If you would colour it yellow, steep your parchment, after it has been washed, in a yellow liquid, made of saffron; for which purpose, tie saffron in a thin linen rag, hang it in a weak ley, and warm it over a slow fire; and when you see the ley tinted yellow, it is fit for use.

For a transparent red.—Take brazil, as much as you will: put it into a hot ley, which is clear, and not too strong, and

it will tincture the ley of a fine red; then pour to it about half an egg-shell full of clean wine; draw the parchment through the colour; and when it is as deep as you would have it, strain it as before.

For a blue.—Take Lombard indigo, grind it with vinegar on a stone, and mix sal ammoniac among it, to the quantity of a pea; with this wet your parchment, and proceed as has been directed for the green.

For a violet or purple Colour.—Temper two-thirds of the above red, and one-third of the blue, and use it as before directed.

For a black Colour.—Take Roman alum, beat it into powder, and boil it in rain-water to a fourth part; add Roman vitriol, or atrament, with some Roman galls, and boil them together: with this stain your parchment twice or three times over; and, when dry, lay the Spanish varnish over it.

N. B. With these transparent parchments you may make curious bindings. One sort, used at Rome, is made thus: lay the board or pasteboard over with leaf-gold, leaf-silver, staniel, metal-leaves, &c. then binding the parchment over it, it will give it an uncommon lustre and beauty.

Dr. Lewis informs us, that, in order to render the ink durable on parchment, a thick piece of it should be steeped in water, with some oak-bark, for three or four days, and then pressed smooth and dried. When the surface of this parchment was pared off, and the internal part written upon, the characters continued of a good black, while those made with the same ink, on unprepared parchment, were changed into a yellowish-brown. Velium may also be treated in the same manner.

It is said, that writing upon parchments decayed by time, may be recovered, and rendered legible, by dipping the obliterated parchment into a vessel of cold water, fresh drawn from the well; let it be taken out in about a minute, and pressed between two papers, in order to prevent its crumpling up in drying. As soon as it is moderately dry, if it be not legible, repeat the operation two or three times.

PARCHMENT, Roll of. See ROLL.

Parting

PARTING, in the art of refining metals, is a process by which gold is separated from silver. When those metals which are oxydable in the cupel have been separated from gold, the silver not undergoing that change remains alloyed with it. This is always the case in refining jewellers' gold. In order to separate the silver, the alloy is first rolled into very thin plates, the thinner the better; these plates are to be boiled with pure nitric acid. By this means, the silver is dissolved by the nitric acid, giving to the plates a corroded appearance, as if perforated with a small instrument. When the silver ceases to be dissolved, the plates are to be melted. If the gold is required of greater purity, it may be rolled in plates, and exposed to the acid a second time. If the nitric acid contains any muriatic acid, which is generally the case with the acid of commerce, some of the gold will always be dissolved. Should this be the case, the silver should first be precipitated in the form of muriat, with common salt, and the gold afterwards thrown down with green sulphat of iron.

The most effectual method of separating gold from silver is to dissolve the whole of the thin plates in nitro-muriatic

acid. The silver will be found at the bottom of the vessel in the form of muriat, while the gold remains in solution, and may be precipitated with sulphat of iron. The silver may be obtained by heating the muriat with soda in a crucible. The muriat of soda sublimes, while the silver is left pure. See **ASSAYING**.

PARTING, Dry, or parting by fusion, is performed by sulphur, which has the property of uniting easily with silver, while it does not attack gold. The most advantageous method, says Dr. Lewis, of separating a small portion of gold from a large one of silver, appears to be by means of sulphur, which unites with and scorifies the silver without affecting the gold: but as sulphurated silver does not flow thin enough to suffer the small particles of gold diffused through it to re-unite and settle at the bottom, some addition is necessary for collecting and carrying them down.

In order to the commixture with the sulphur, fifty or sixty pounds of the mixed metal, or as much as a large crucible will receive, are melted at once, and reduced into grains by lading out the fluid matter, with a small crucible made red-hot, and pouring it into cold water stirred

with a rapid circular motion. From an eighth to a fifth of the granulated metal, according as it is richer or poorer in gold, is reserved; and the rest well mingled with an eighth of powdered sulphur. The grains enveloped with the sulphur are again put into the crucible, and the fire kept gentle for some time, that the silver, before it melts, may be thoroughly penetrated by the sulphur; if the fire was hastily urged, great part of the sulphur would be dissipated without acting upon the metal.

If to sulphurated silver in fusion pure silver be added, the latter falls to the bottom, and forms there a distinct fluid, not miscible with the other. The particles of gold, having no affinity with the sulphurated silver, join themselves to the pure silver, wherever they come in contact with it, and are thus transferred from the former into the latter, more or less perfectly according as the pure silver was more or less thoroughly diffused through the mixed. It is for this use that a part of the granulated metal was reserved. The sulphurated mass being brought into perfect fusion, and kept melted for near an hour in a close covered crucible, one-third of the reserved grains is thrown in; and as soon as this is melted, the whole is well stirred, that the fresh silver may be distributed through the mixed, to collect the gold from it. The stirring is performed with a wooden rod; an iron one would be corroded by the sulphur, so as to deprive the mixed of its due quantity of sulphur, and likewise render the subsequent purification of the silver more troublesome. The fusion being continued an hour longer, another third of the unsulphurated grains is added, and an hour after this the remainder; after which the fusion is farther continued for some time, the matter being stirred at least every half hour from the beginning to the end, and the crucible kept closely covered in the intervals.

The sulphurated silver appears in fusion of a dark brown colour: after it has been kept melted for a certain time, a part of the sulphur having escaped from the top, the surface becomes white, and some bright drops of silver, about the size of peas, are perceived on it. When this happens, which is commonly in about three hours after the last addition of the reserved grains, sooner or later, according as the crucible has been more or less closely covered, and the matter more or less stirred, the fire must be immediately discontinued; for otherwise more and more of the silver, thus losing its sulphur, would subside and mingle with the part at the bottom in which the gold is collected. The whole is poured out into an iron mortar greased and duly heated; or if the quantity is too large to be safely lifted at once, a part is first laded out from the top with a small crucible, and the rest poured into the mortar. The gold, diffused at first through the whole mass, is now found collected into a part of it at the bottom, amounting only to about as much as was reserved unsulphurated. This part may be separated from the sulphurated silver above it by a chissel and hammer; or more perfectly, the surface of the lower mass being generally rugged and unequal, by placing the whole mass with its bottom upwards in a crucible: the sulphurated part quickly melts, leaving unmelted that which contains the gold, which may thus be completely separated from the other. The sulphurated silver is essayed, by keeping a portion of it in fusion in an open crucible, till the sulphur is dissipated; and then dissolving it in aqua fortis. If it should still be found to contain any gold, it is to be melted again; as much more unsulphurated silver is to be added as was employed in each of the former in-

jections, and the fusion continued about an hour and a half.

The gold thus collected into a part of the silver may be farther concentrated into a smaller part, by granulating the mass and separating the whole process. The operation may be again and again repeated, till so much of the silver is separated, that the remainder may be parted by aqua fortis without too much expence.

The foregoing process, according to Mr. Schlutter, is practised at Rammelsberg, in the Lower Hartz. The prevailing metal in the ore of Rammelsberg is lead: the quantity of lead is at most forty pounds in a quintal or hundred pounds of the ore. The lead worked off on a test or concave hearth yields about a hundred and ten grains of silver, and the silver contains only a three hundred and eighty-fourth part of gold; yet this little quantity of gold, amounting scarcely to a third of a grain in a hundred weight of the ore, is thus collected with profit. The author above mentioned confines this method of separation to such silver as is poor in gold, and reckons parting with aqua fortis more advantageous where the gold amounts to above a sixty-fourth of the silver: he advises also not to attempt concentrating the gold too far, as a portion of it will always be taken up again by the silver. Mr. Scheffer, however, relates (in the Swedish Memoirs for the year 1752), that he has by this method brought the gold to perfect fineness; and that he has likewise collected all the gold which the silver contained; the silver of the last operations, which had taken up a portion of the gold, being reserved to be worked over again with a fresh quantity of gold-holding silver. The sulphurated silver is purified by continuing it in fusion for some time with a large surface exposed to the air; the sulphur gradually exhales, and leaves the silver entire. Lewis's Comp. Phil. Techn. p. 161, &c. See GOLD and REFINING.

PARTING-Glasses are used in the operation of parting: they have the form of truncated cones, the bottom being commonly about seven inches wide, the aperture about one or two inches wide, and the height about twelve inches. These glass vessels ought to have been well annealed, and chosen free from flaws; as one of the chief inconveniences attending the operation is, that the glasses are apt to crack by exposure to cold, and even when touched by the hand. Some operators secure their glasses by a coating. For this purpose they spread a mixture of quick lime slaked with beer and whites of eggs upon linen cloth, which they wrap round the lower part of the vessel, leaving the upper part uncovered, that they may see the progress of the operation; and over this cloth they apply a composition of clay and hair. Schlutter advises to put the parting-glasses in copper vessels containing some water, and supported by trevets, with fire under them. When the heat communicated by the water is too great, it may be diminished by adding cold water, which must be done very carefully by pouring against the sides of the pan, to prevent too sudden an application of cold to the parting-glass. The intention of this contrivance is, that the contents of the glasses, if these should break, may be received by the copper vessel. Into a glass fifteen inches high, and ten or twelve inches wide at bottom, placed in a copper pan twelve inches wide at bottom, fifteen inches wide at top, and ten inches high, he usually put about eighty ounces of metal, with twice as much aqua fortis.

Pastes

PASTES, in the *Glass Trade*, a sort of composition of the glass kind, made from calcined crystal, lead, and metallic preparations, to imitate the several natural gems. These are no way inferior to the native stones, when carefully made and well polished, in brightness and transparency, but want their hardness.

The general rules to be observed in making them are these: 1. That all the vessels in which they are made are firmly luted, and the lute left to dry before they are put into the fire. 2. That such vessels are chosen for the work

as will bear the fire well. 3. That the powders be prepared on a porphyry stone, not in a metal mortar, which would communicate a tinge to them. 4. That the just proportion in the quantities of the several ingredients be nicely observed. 5. That the materials be all well mixed; and if not sufficiently baked the first time, to be committed to the fire again, without breaking the pot; for, if this be not observed, they will be full of blisters and air-bladders. 6. That a small vacancy be always left at the top of the pot, to give room to the swelling of the ingredients.

To make a paste of extreme hardness, and capable of all

the colours of the gems, with great lustre and beauty, take of prepared crystal ten pounds; salt of pulverine, six pounds; sulphur of lead, two pounds: mix all these well together, into a fine powder; make the whole, with common water, into a hard paste; and make of this paste small cakes, of about three ounces weight each, with a hole in them, made in their middle: dry these in the sun, and afterwards calcine them in the straightest part of a potter's furnace; after this powder them, and levigate them into a perfect fineness on a porphyry, and set this powder in pots in a glass furnace to purify for three days; then cast the whole into water, and afterwards return it into the furnace, where let it stand fifteen days; in which time all foulness and blisters will disappear, and the paste will greatly resemble the natural jewels. To give this the colour of the emerald, add to it brass thrice calcined; for a sea-green, brass simply calcined to redness; for a sapphire, add zaffer, with manganese; and for a topaz, manganese and tartar. All the gems are thus imitated in paste, by the same way of working as the making of the coloured glasses; and this is so hard, that they very much approach to the natural gems.

The colours in all the counterfeit gems, made of the several pastes, may be made deeper or lighter, according to the works for which the stones are designed; and it is a necessary general rule, that small stones for rings, &c. require a deeper colour, and large ones a paler. Besides the colours made from manganese, verdigris, and zaffer, which are the ingredients commonly used, there are other very fine ones, which care and skill may prepare: very fine red may be made from gold, and one not much inferior to that from iron; a very fine green from brass or copper, and a sky-colour from silver; and a much finer one from the common small garnets of Bohemia, which are of little value. The gems also afford glorious colours like their own.

The fine blue from silver is, probably, only from the small quantity of copper used in the alloy.

A very singular and excellent way of making the paste to imitate the coloured gems is this: take a quantity of faccharum saturni, or sugar of lead, made with vinegar in the common way; set it in sand, in a glass body well luted from the neck downwards; leave the mouth of the glass open, and continue the fire twenty-four hours; then take out the salt, and if it be not red, but yellowish, powder it fine, and return it into the vessel, and keep it in the sand-heat twenty-four hours more, till it becomes as red as cinnabar. The fire must not be made so strong as to melt it, for then all the process is spoiled. Pour distilled vinegar on this calcined salt, and separate the solution from the dregs: let the decanted liquor stand six days in an earthen vessel, to give time for the finer sediment to subside: filter this liquor, and evaporate it in a glass body, and there will remain a most pure salt of lead; dry this well, then dissolve it in fair water; let the solution stand six days in a glazed pan; let it subside, then filter the clear solution, and evaporate it to a yet more pure white and sweet salt; repeat this operation three times; put the now perfectly pure salt into a glass vessel, set it in a sand-heat for several days, and it will be calcined to a fine impalpable powder, of a lively red. This is called the sulphur of lead. Neri's Art of Glass.

Take all the ingredients as in the common composition of the pastes of the several colours, only instead of red lead, use this powder, and the produce will well reward the trouble of the operation, as experience has often proved.

A paste proper for receiving colours may be readily made by well pounding and mixing six pounds of white sand, cleaned, three pounds of red lead, two pounds of purified pearl-ashes, and one pound of nitre. A softer paste may be

made, in the same manner, of six pounds of white sand cleaned; red lead, and purified pearl-ashes, of each three pounds; one pound of nitre, half a pound of borax, and three ounces of arsenic. For common use, a pound of common salt may be substituted for the borax. This glass will be very soft, and will not bear much wear, if employed for rings, buckles, or such imitations of stones, as are exposed to much rubbing; but for ear-rings, ornaments worn on the breast, and those little used, it may last a considerable time.

In order to give paste different colours, the process is as follows.

PASTE resembling amethyst.—Take ten pounds of either of the compositions described under *Colouring of GLASS*; one ounce and a half of manganese, and one dram of zaffer; powder and fuse them together. See *AMETHYST*.

PASTE perfectly black.—Take ten pounds of either of the compositions just referred to, one ounce of zaffer, six drams of manganese, and five drams of iron, highly calcined; and proceed as before.

PASTE, Blue.—Take of the same composition ten pounds; of zaffer, six drams; and of manganese, two drams; and proceed as with the foregoing.

PASTE resembling the chrysolite.—Take of either of the compositions for paste above described, prepared without saltpetre, ten pounds, and of calcined iron five drams; and pursue the same process as with the rest. See *CHRYSOLITE*.

PASTE resembling the red cornelian.—Take of the compositions mentioned under *Colouring of GLASS*, two pounds; of glass of antimony, one pound; of the calcined vitriol, called scarlet ochre, two ounces; and of manganese, one dram. Fuse the glass of antimony and manganese with the composition; then powder them, and mix them with the other, by grinding them together, and fuse them with a gentle heat.

PASTE resembling white cornelian.—Take of the composition just referred to, two pounds; and of yellow ochre, well washed, two drams; and of calcined bones, one ounce. Mix them and fuse them with a gentle heat.

PASTE resembling the diamond.—Take of the white sand, six pounds; of red lead, four pounds; of pearl-ashes, purified, three pounds; of nitre, two pounds; of arsenic, five ounces; and of manganese one scruple. Powder and fuse them.

PASTE resembling the eagle-marine.—Take ten pounds of the composition under *GLASS*; three ounces of copper, highly calcined with sulphur; and one scruple of zaffer. Proceed as before.

PASTE like emerald.—Take of the same composition with the last, nine pounds; three ounces of copper, precipitated from aquafortis, and two drams of precipitated iron. See *EMERALD*.

PASTE like garnet.—Take two pounds of the composition under *GLASS*; two pounds of the glass of antimony, and two drams of manganese. For vinegar garnet, take of the composition for paste, described in this article, two pounds; one pound of glass of antimony, and half an ounce of iron, highly calcined; mix the iron with the uncoloured paste, and fuse them; then add the glass of antimony, powdered, and continue them in the heat till the whole is incorporated. See *GRANITE*.

PASTE, gold, or full yellow colour.—Take of the composition for paste ten pounds, and one ounce and a half of iron strongly calcined; proceeding as with the others.

PASTE, deep purple.—Take of either of the compositions for paste ten pounds; of manganese, one ounce; and of zaffer, half an ounce.

PASTE, resembling ruby.—Take one pound of either of the compositions for paste, and two drams of *calx cassii*, or precipitation of gold by tin; powder the paste, and grind the calx of gold with it in a glass, flint, or agate mortar, and then fuse them together. A cheaper ruby paste may be made with half a pound of either of the above compositions, half a pound of glass of antimony, and one dram and a half of the calx of gold; proceeding as before.

PASTE resembling sapphire.—Take of the composition for paste, ten pounds; of saffron, three drams and one scruple; and of the calx cassii one dram. Powder and fuse them. Or the same may be done, by mixing with the paste one-

eighth of its weight of smalt. See **SAPPHIRE**.

PASTE like topaz.—Take of the composition under **GLASS** ten pounds, omitting the salt-petre; and an equal quantity of the gold-coloured hard glass. Powder and fuse them. See **TOPAZ**.

PASTE like turquoise.—Take of the composition for blue paste, already described, ten pounds; of calcined bone, horn, or ivory, half a pound. Powder and fuse them.

PASTE, opaque white.—Take of the composition for paste, ten pounds; and one pound of calcined horn, ivory, or bone; and proceed as before.

PASTE, semi-transparent white, like opal. See **OPAL**.

Patents

PATENTS, or *Letters Patent*, in *Law*, the king's letters, sealed with the great seal, serving to convey the title or property of some grant, favour, privilege of a new establishment, or the like. See *LETTERS Patent*.

They have their name from their being delivered open, *ut pateant omnibus*; by way of contradistinction from *letters de cachet*, or *litteræ clausæ*, or *close rolls*, which are sealed.

Grants or letters patent must first pass by bill; which is prepared by the attorney or solicitor general, in consequence of a warrant from the crown; and is then signed, that is, superscribed at the top, with the king's own sign manual, and sealed with his privy signet, which is always in the custody of the principal secretary of state; and then sometimes it immediately passes under the great seal, in which case the patent is subscribed in these words, "per ipsum regem; by the king himself." Otherwise the course is to carry an extract of the bill to the keeper of the privy seal, who makes out a writ or warrant thereupon to the chancery; so that the sign manual is the warrant to the privy seal, and the privy seal is the warrant to the great seal: and in this last case the patent is subscribed, "per breve de privato sigillo, by writ of privy seal."

It is to be noted, that patents differ from writs: a coroner is made by *writ*, not by patent.

To this office, enacted 18 Jac. I. belongs a clerk, &c.

PATENT, *Letters*, under the royal authority, confer on a person the exclusive privilege of making and selling any thing, so that no person be restrained in what he had before, or in using his lawful trade. The latter part of the definition of letters patent, or of a monopoly conferred by letters patent, will apply only to such as have been granted since the statute of the 21st of James, c. 2, commonly called the statute of Monopolies; prior to that period, letters patent conferred such a monopoly as interfered with the rights of other people, and restricted the freedom of trade.

Monopoly, in the latter acceptation of the word, has already been considered under its proper head: it existed in this kingdom unrestrained till the time of king John, who first granted municipal franchises. In the 25th year of the reign of Edward III. a statute was passed, which granted a free trade equally to foreigners and natives; this statute, however, was afterwards repealed; and monopolies that not only excluded foreigners from the advantages of English trade, but also injured the English nation at large; in order that the favourites of monarchs might be rewarded, or that the crown might be enriched, were established. During the reign of queen Elizabeth, they had spread so widely over the commercial transactions of the country, as to threaten the utter ruin of trade; when a list of only part of the commodities, which had been appropriated to monopolists, was read in the house of commons, a member cried, "Is not bread in the number?" "Bread," said every one with astonishment; "yes, I assure you," replied he, "if affairs

go on at this rate, we shall have bread reduced to a monopoly before next parliament." At this period, most extraordinary powers were granted to the patentees; especially to those who held the exclusive privilege of selling saltpetre; they had the power of entering every house, and of committing what havoc they pleased in stables, cellars, or wherever they suspected saltpetre might be gathered. Hume.

It might have been supposed, that such a sagacious prince as Elizabeth would have perceived the evil consequences of granting monopolies; but either the reduced state of the royal funds, or her fondness for favourites, blinded her to the true interests of her people. Towards the end of her reign, however, the clamour of the country was loud and general, that she sent a message to parliament, that she would immediately cancel the most oppressive of the exclusive privileges she had granted.

Before proceeding to the consideration of the statute of James I. already alluded to, it may be proper very briefly to take a view of the statute law, as it respects patents prior to that period. Monopolies are expressly contrary to Magna Charta, (29, 30.) The statute of Edward III. declared all grants by monopolies void; and when Philip and Mary granted by letters patent, to the mayor, bailiffs, and burghesses of Southampton, the exclusive privilege of importing Malmsey wine at that place, the judges were unanimous in their opinion, that the statute was void, as being against the freedom of trade. The principal statutes relating to patents in the 16th, and in the beginning of the 17th century, were in the 6th of Henry VIII., the 4th of Edward VI., and the 13th and 43d of Elizabeth.

The 21st of James I. ch. 3, is regarded as the declaration statute, by which the law on this subject is determined; and the 6th section of this statute particularly relates to patents for new inventions: this section contains the exception to the general law of the statute; the general law is, that all monopolies, and all commissions, grants, licences, letters patent, &c. for the sole buying, selling, making, using, &c. of any thing, shall be void; the excepting clause declares, that the law of the statute shall not extend to any letters patent, for the term of 14 years or under, granted to the true and first inventor, or inventors of manufactures, &c. which others, at the time of making such letters patent, shall not use. Sir Edward Coke, in his explication of this statute, gives it as his opinion, that the new manufacture, to which letters patent may be granted, must not be generally inconvenient; and this construction seems to have been adopted in his time, as he says, that a patent for a fulling-mill to thicken bonnets and caps, was set aside, on the ground, that it was holden inconvenient to turn labouring men to idleness. But this construction does not prevail now, and, indeed, if it did, it would effectually defeat the object of the sixth section of the statute of monopolies.

In the letters patent which are granted for new inventions, the improvements or inventions are first stated; the prayer of the petitioner to have the exclusive benefit for himself, or his assigns, for fourteen years, is next given; and this prayer is declared to be complied with, according to the statute. After commanding all subjects not to interfere with the patent right, and issuing a mandate to all officers not to molest the patentee in the exercise of it, the letters patent declare the patent void, if it appear that the grant is contrary to law, or prejudicial to the subject; or if the thing invented have been in use before the date of the grant; or if the patentee be not the inventor; or if it interfere with prior letters patent; or if the patent be transferred to more than five persons, or to any who act as a corporate body; or finally, if the nature of the invention be not described, or the description be not enrolled within one calendar month after the date of the letters patent. The letters patent conclude with a declaration, that they shall be construed in the most beneficial sense for the patentee.

A writ of *scire facias*, to repeal letters patent, lies in three cases; 1st, when the king grants the same thing to two or more persons; 2dly, when the king is deceived in his grant; and 3dly, when the grant is against law. The following rules are laid down by chief justice Lee, respecting the cases in which mistakes do not vitiate the grant: 1. If the king's intention is manifest, a false recital in a thing not material, will not vitiate the grant. 2. It is not vitiated in cases where the king is deceived, not by the false suggestion of the party, but by his own mistake, upon the surmise and information of the party. And 3. Although the king is mistaken in point of law, or matter of fact, if that is not part of the consideration of the grant, it will not vitiate it.

Patents for new inventions are granted for a term of fourteen years; and any royal grant for such purpose beyond that term is void. The fourteen years are accounted to commence from the date of the first letters patent. The patent right, however, may be extended by act of parliament.

A patent may be granted for an improvement on an old manufacture; but the improvement must be material and useful; and the patent extends to the improvement only. The statute considers a manufacture brought from abroad into the kingdom (provided it has not been practised before) as a new manufacture, and entitled to letters patent. No old manufacture in use before, can be prohibited by the grant of the sole use of a new invention; nor can a patent be granted for a method, or principle; its object must be some substantial thing produced.

The following rules are laid down by judge Butler, respecting the description required in the specification, which by the patent grant, the patentee is to cause to be enrolled in the high court of chancery. The invention or improvement must be disclosed, and described in such a manner, that others of the same trade may be taught to do the same thing for which the patent is granted: 2. He must describe it in such a manner, that the public, after the expiration of the term, may have the use of the invention in as cheap and beneficial way as the patentee himself; and therefore, if the specification describes many parts of a machine, &c., and the patentee uses only a few of them, or does not state how they are to be put together, the patent is void. 3. If the specification be in any part materially false or defective, the patent is against law, and cannot be supported.

The enrolment of the specification in the high court of chancery, where it is open to the inspection of every one, enables those who are inclined to purchase the machine, in-

vention, &c., to become acquainted with its nature and merits; and, at the same time, prevents such as are employing their skill, time, and money on improvements, or inventions of a similar nature, from merely doing what has been done before.

With respect to the form of the specification, it must be under the hand and seal of the inventor; the enrolment must take place within one calendar month after the date of the letters patent; if the patentee passes over this time, it cannot be enlarged without an act of parliament for that express purpose.

When a patentee brings an action against any person for infringing his patent, it is incumbent on him to shew, that the invention was new, and that the specification is full and complete.

It is frequently for the convenience or interest of a person, who has invented or improved a machine, &c. to delay taking out a patent for it; in this case, he may enter a *caveat*. A *caveat* will protect his invention or improvement for the space of one year, after which, if he have not brought his contrivance to maturity, he may renew it again for an equal period, and so on for any successive number of years. The caveat must be delivered at the chambers of the attorney and solicitor-general; and if an application be made for a patent for an invention of the same nature, notice is given to the person who has entered the caveat: if he requires it, the attorney-general gives a separate audience to each of the rival inventors, and makes his report to the king, according to his opinion respecting the priority of invention. A petition to the king, stating the nature of the invention, and praying letters patent, accompanied by an oath taken before a master in chancery, that the invention is new, are the steps preparatory to taking out a patent. Separate patents must be taken out for England, Scotland, and Ireland; but in a patent for England, the patentee may, on the payment of a small additional sum, have the colonies and plantations abroad included. The petition and oath are referred by the secretary of state for the home department to the attorney-general, and on his report, recommending letters patent, his majesty issues his warrant, in consequence of which the bill is made out, which is the grant of his majesty, and of this the patent is the transcript; the nature of the specification, and the enrolment of it, have been already noticed.

Having thus considered letters patent in a legal light, we shall conclude with a few remarks on them, as a subject of political economy. It is plain from what we have stated, that they are the remains of that system of monopoly, which formerly prevailed in this and all the other countries of Europe; and so far, at first sight, they may appear objectionable. But when we consider the object for which they are granted, we shall probably be of opinion, that it takes them completely out of the force of those objections, which are so justly brought against all monopolies.

It is evident; that no man will bestow his time, ingenuity, and money, in endeavouring to invent or improve any thing, unless, when he has succeeded, he is secure in being rewarded. This reward can be secured to him, only by granting him, for a certain number of years, the exclusive privilege of his invention or improvement; or by government purchasing it from him. In the former case, while his patent right lasts, he has a monopoly; he may put what prices on his invention he pleases; or he may execute it in a careless or improper manner; but, on the other hand, the public will in a great measure be protected from too high a price, by the alternative they have, of following the old methods; and if they gain by purchasing the new invention, the price put upon it by the inventor can hardly be

said to be exorbitant. With respect to his doing his work in a careless manner, the public are equally guarded against this ; for by such conduct, he would act against his own interest, and the sale of his invention.

If, indeed, we could suppose that government would examine, in all cases, thoroughly, impartially, and scientifically, into the merits of every invention, it might be better for them to throw it open to the public, by rewarding the

inventor, though in this case, the nation at large would pay for what directly and materially benefited only certain classes, whereas, by letters patent, those reward the inventor, whose interest it is to reward him. On the whole, therefore, the present mode is the best, with perhaps this alteration, that the letters patent should vary in their duration, according to the importance of the invention, and the money and time expended by the inventor.

Pavement

PAVEMENT, a layer or stratum of stone, or other matter, serving to cover and strengthen the ground of divers places, for the more commodious walking on, or for the passage of carriages.

The word is formed from the Latin *pavimentum*, of *pavire*, to beat down the earth, in order to make it firm and strong.

In England, the pavements of the grand streets, &c. are usually of flint or rubble-stone; courts, stables, kitchens, halls, churches, &c. are paved with tiles, bricks, flags, or fire-stone; sometimes with a kind of free-stone, and rag-stone.

In some cities, *e. gr.* of Venice, the streets, &c. are paved with brick; churches sometimes are paved with marble, and sometimes with mosaic work, as the church of St. Mark, at Venice. In France, the public roads, streets, courts, &c. are paved with gres or grit, a kind of free-stone.

In Amsterdam, and the chief cities of Holland, they call their brick pavement the *burgher-master's* pavement, to distinguish it from the stone or flint pavement, which usually takes up the middle of the street, and which serves for carriages; the brick which borders it being destined for the passage of people on foot.

Pavements of free-stone, flint, and flags, in streets, &c. are laid dry, *i. e.* in a bed of sand; those of courts, stables, ground-rooms, &c. are laid in a mortar of lime and sand; or in lime and cement, especially if there be vaults or cellars underneath. Some masons, after laying a floor dry, especially of brick, spread a thin mortar over it; sweeping it backwards and forwards to fill up the joints. The several kinds of pavement are as various as the materials of which they are composed, and whence they derive the name by which they are distinguished: as, 1. *Pebble-paving*, which is done

with stones collected from the sea-beach, mostly brought from the islands of Guernsey and Jersey; they are very durable, indeed the most so of any stone used for this purpose. They are used of various sizes, but those which are from six to nine inches deep, are esteemed the most serviceable. When they are about three inches deep they are denominated bolders, or bowlers; these are used for paving court-yards, and other places not accustomed to receive carriages with heavy weights; when laid in geometrical figures they have a very pleasing appearance.

2. *Rag paving* was formerly much used in London, but is very inferior to the pebbles; it is dug in the vicinity of Maidstone, in Kent, from whence it has the name of Kentish rag-stone; there are squared stones of this material for paving coach-tracks and footways.

3. *Purbeck pitchens*; squared stones used in footways; they are brought from the island of Purbeck, and also frequently used in court-yards; they are in general from six to ten inches square, and about five inches deep.

4. *Squared paving*, for distinction by some called *Scotch paving*, because the first of the kind paved in the manner that has been and continues to be paved, came from Scotland; the first was a clear close stone, called blue wynn, which is now disused, because it has been found inferior to others since introduced in the order they are hereafter placed.

5. *Granite*, a hard material, brought also from Scotland, of a reddish colour, very superior to the blue wynn quarry.

6. *Guernsey*, which is the best, and now almost the only stone in use; it is the same stone with the pebble before spoken of, but broken with iron hammers, and squared to any dimensions required of a prismoidal figure, set with its smallest base downwards. The whole of the foregoing paving should be bedded and paved in small gravel.

7. *Purbeck paving*, for footways, is in general got in large surfaces, about two inches and a half thick; the blue sort is the hardest and the best of this kind of paving.

8. *Yorkshire paving*, is an exceeding good material for the same purpose, and is got of almost any dimensions of the same thickness of the Purbeck; this stone will not admit the wet to pass through it, nor is it affected by the frost.

9. *Ryegate, or fire stone paving*, is used for hearths, stoves, ovens, and such places as are liable to great heat, which does not affect this stone, if kept dry.

10. *Newcastle flags*, are stones about two feet square, and one and a half, or two inches thick; they answer very well for paving out-offices; they are somewhat like the Yorkshire.

11. *Portland paving*, with stone from the island of Portland; this is sometimes ornamented with black marble dots.

12. *Scotland paving*, is a black slate dug in Leicestershire, and looks well for paving halls, or in parti-coloured paving.

13. *Marble paving*, is mostly variegated with different marbles, sometimes inlaid in mosaic.

14. *Flat brick paving*, done with brick laid in sand, mortar, or grout, as when liquid lime is poured into the joints.

15. *Brick on edge paving*, done with brick laid edgewise in the same manner.

16. Bricks are also laid flat or edgewise in herringbone.

17. Bricks are also sometimes set endways in sand, mortar, or grout.

18. Paving is also performed with paving bricks.

19. With ten-inch tiles.

20. With foot-tiles.

21. With clinkers for stables and out-offices.

22. With the bones of animals, for gardens, &c. And

23. We have knob-paving, with large gravel-stones for porticoes, garden-seats, &c.

Pavers' work is done by the square yard: and the content is found by multiplying the length by the breadth.

Pavements of churches, &c. frequently consist of stones of several colours; chiefly black and white, and of several forms, but chiefly square, and lozenges, artfully disposed. Indeed, there needs no great variety of colours to make a surprising diversity of figures and arrangements. M. Truchet, in the Memoirs of the French Academy, has shewn by the rules of combination, that two square stones, divided diagonally into two colours, may be joined together chequerwise sixty-four different ways: which appears surprising enough; since two letters, or figures, can only be combined two ways.

The reason is, that letters only change their situation with regard to the first and second; the top and bottom remaining the same: but in the arrangement of these stones, each admits of four several situations, in each of which the other square may be changed sixteen times, which gives sixty-four combinations.

Indeed, from a farther examination of these sixty-four combinations, he found there were only thirty-two different figures; each figure being repeated twice in the same situation, though in a different combination; so that the two only differed from each other by the transposition of the dark and light parts.

The paving of streets is one of the most beneficial regulations of police that have been transmitted to us from our ancestors. Several cities had paved streets before the commencement of the Christian era; nevertheless those which are at present the ornament of Europe, Rome excepted, were destitute of this great advantage till almost the 12th or 13th century. It is probable that those people who first carried on the greatest trade, were the first who paid attention to have good streets and highways, in order to facilitate that intercourse which is so necessary to keep up the spirit of commerce. Accordingly we are told by Isidorus (Origin. l. xv. c. 16.) that the Carthaginians had the first paved streets, and that their example was soon copied by the Romans. Long before that period, however, Semiramis paved highways, as appears by the vain-glorious inscription which she herself caused to be put up. (Strabo, l. xvi. Diod. Sicul. l. ii. v. 13. Polyæni Stratagem. l. viii. c. 26.) The streets of Thebes, and probably those of Jerusalem, were paved. But neither the streets of Rome, nor the roads around it, were paved during the time of its kings. In the year 188, after the abolition of the monarchical form of government, Appius Claudius, being then censor, constructed the first real highway, called after him the Appian way, and on account of its excellence, the queen of roads. The time when the streets were first paved cannot be precisely ascertained; some have referred this improvement to the year 578, after the building of the city; others to 584; and others to 459; at which several periods some parts of the city and suburbs might have been paved. That streets paved with lava, having deep ruts made by the wheels of carriages, and raised banks on each side, for the accommodation of foot-passengers, were found both at Herculaneum and Pompeii, is well known.

Of modern cities, the oldest pavement is commonly ascribed to that of Paris; but it is certain that Cordova in Spain was paved so early as the middle of the 9th century, or about the year 850. The capital of France was not paved in the 12th century, but the orders for this purpose were issued by the government in the year 1184, on which occasion it is said that the name of Lutetia, deduced from its dirtiness, was changed into that of Paris. Nevertheless, in the year 1641, the streets in many quarters of Paris were not paved. That the streets of London were not paved at the end of the 11th century, is asserted by all historians. It does not appear when paving was first introduced; but it was gradually extended as trade and opulence increased. Several of the principal streets, such as Holborn, which are at present in the middle of the city, were paved for the first time by royal command in the year 1417; others were paved under Henry VIII., some in the suburbs in 1544, others in 1571 and 1605, and the great market of Smithfield, in 1614.

PAVEMENT of Terrace, is that which serves for covering in manner of a platform; whether it be over a vault or a wooden floor.

Those over vaults are usually stones squared, and bedded in lead. Those on wood, called by the Latins *pavimenta contignata*, are either stones with beds for bridges, tiles for ceiling of rooms, or lays of mortar made of cement and lime, with flints or bricks laid flat: as is still practised by the eastern and southern people a-top of their houses.

All those pavements which lie open were called by the Latins *pavimenta subdialia*.

Pearl-ash

PEARL-Asb, in *Chemistry, Arts, and Manufactures*. The crude potash, when first obtained by the combustion of vegetable matter, abounds with a great variety of impurities, consisting of neutral salts, sulphur, charcoal, and some earthy matter.

When this substance is washed with clean water, and the insoluble matter allowed to subside, the clear liquor is evaporated in large shallow iron pans. The residuum consists of potash properly so called, still containing some neutral salts, but free from its other impurities. It is a mass of a white colour, from which it is called pearl-ash. In this state it is used by bleachers, glass-makers, dyers, and others. The real potash it contains, for which it is valued, is combined with carbonic acid in the proportion of 19 of acid to 42 potash. The remainder consists of sulphat and muriat of potash. See **CARBONAT of Potash**.

The goodness of pearl-ashes must be distinguished by the uniform and white appearance of them: they are subject, however, to a common adulteration, not easily distinguishable by the appearance, which is done by the addition of common salt. In order to discover this fraud, take a small quantity of the suspected salt, and after it has been softened by lying in the air, put it over the fire in a shovel: if it contains any common salt, a crackling and kind of slight explosion will take place, as the salt grows hot.

The pearl-ashes are much used in the manufacture of glass, and require no preparation; except where very great transparency is required, as in the case of looking-glasses, and the best window-glass. For this purpose dissolve them in four times their weight of boiling water: when they are dissolved, let the solution be put into a clean tub, and suffered to remain there twenty-four hours, or longer. Let the clear part of the fluid be then decanted off from the sediment, and put back into the iron pot in which the solution was made: in this let the water be evaporated away till the salts be left perfectly dry again. Keep those that are not designed for immediate use in stone jars, well secured from moisture and air.

To those who buy large quantities of this article, it may not be useless to know the means of assaying it. Weigh 100 grains of it before it has been exposed to the air; then

lay out a known weight of sulphuric acid, of the specific gravity of 1.8, or such as boils at the temperature of 460°. Dissolve the pearl-ash in its own weight of distilled water. With a small sucking tube add sulphuric acid by a small portion at once, till no more effervescence takes place. The weight of the remainder of the sulphuric acid will shew how much has been added to the solution. Then for every grain of sulphuric acid of the above strength taken up, allow .82 of a grain of pure potash. Thus, if 100 grains of the pearl-ash take up 40 grains of sulphuric acid, of the specific gravity 1.8, the pure potash contained in the 100 will be 32.8 grains. See **POTASH**.

PEARL-Barley. (See **BARLEY**.) This affords, to a microscopic observer, a peculiar kind of mite worthy of attention, and very different from the common species. The bodies of these have some brown marks upon them, and have not such long hairs as the common mites have; the hinder part of the body also is of a different make. They have eight legs; and before the head there stand two weapons twice as thick as the legs, and of about half their length: these are divided towards their ends with joints like fingers, and those have at their ends a sort of nails formed with sharp and crooked claws; and one of the longest joints is serrated at the edge like a saw. These weapons serve not only as arms and hands to seize hold of things, but they also serve as a defence; for as soon as any danger threatens the creature's head, it erects them both, and makes them meet and fold into one another over the head, as we can join our hands and fingers together in the same erect posture. Phil. Trans. No. 222.

PEARL Colour, in *Glass*. This beautiful colour is given to glass in the following manner: put tartar calcined to a whiteness into purified crystal, while in fusion, at several times, in small quantities, mixing it well every time, till the glass is become of the desired colour; and when it is, work it as quick as can be, for it is a colour that is quickly gone. See **GLASS**.

PEARL Shell or Gaper. See **MYA**.

PEARL, Pin, or Web, in *Medicine*, an unnatural speck, or thick film over the eye. See **PANNUS**.

Perambulator

PERAMBULATOR, in *Surveying*, an instrument for the measuring of distances; called also *pedometer*, *way-wifer*, and *surveying-wheel*.

Its advantages are its handiness and expedition: its contrivance is such, that it may be fitted to the wheel of a coach; in which state it performs its office, and measures the road without any trouble at all.

There is some difference in its make; that now most usual, and most convenient, is as follows.

PERAMBULATOR, or *Way-wifer*, *construction of the*. The perambulator (represented *Plate VI. Surveying, fig. 9.*) consists of a wheel two feet seven inches and a half in diameter; consequently half a pole, or eight feet and three inches in circumference. On one end of the axis is a nut, three quarters of an inch in diameter, divided into eight teeth, which, upon moving the wheel round, fall into the eight teeth of another nut *c*, fixed on one end of an iron rod *Q*, and thus turn the rod once round, in the time the wheel makes one revolution. This rod lying along a groove, in the side of a carriage of the instrument, has at its other end a square hole, into which fits the end *b* of the little cylinder *P*. This cylinder is disposed under the dial-plate of a movement, at the end of the carriage *B*, in such manner as to be moveable about its axis. Its end *a* is cut into a perpetual screw; which falling into the thirty-two teeth of a wheel perpendicular to it, upon driving the instrument forward, that wheel makes a revolution, each sixteen poles. On the axis of this wheel is a pinion with six teeth, which, falling into the teeth of another wheel of sixty teeth, carries it round every hundred and sixtieth pole, or half a mile.

This last wheel then carrying a hand or index round with it, over the divisions of the dial-plate, whose outer limb is divided into one hundred and sixty parts, corresponding to the one hundred and sixty poles, points out the number of poles passed over. Again, on the axis of this last wheel is a pinion containing twenty teeth, which, falling into the teeth of a third wheel, that has forty teeth, drives it once round in three hundred and twenty poles, or a mile. On the axis of this wheel is a pinion of twelve teeth, which, falling into the teeth of a fourth wheel, that has seventy-two teeth, drives it once round in twelve miles.

This fourth wheel carrying another index over the inner limb of the dial-plate, divided into twelve, for miles, and each mile subdivided into halves, quarters, and furlongs, serves to register the revolutions of the other hand, and to keep account of the half-miles and miles passed over, as far as twelve miles.

PERAMBULATOR, or *Way-wifer*, *use of the*. The application of this instrument is obvious from its construction. Its proper office is in the surveying of roads, and large distances, where a great deal of expedition, and not much accuracy, is required. It is evident, that driving it along, and observing the hands, has the same effect as dragging the chain, and taking account of the chains and links. See CHAIN.

Long distances, says major Rennell, may be accurately measured by a perambulator; and he says, that during the Bengal survey, he measured a meridian line of three degrees with this instrument; and found it to agree minutely with the observations of latitude. An allowance, however, was made for the irregularities of the ground, whenever they occurred.

Petrol

PETROL, or PETROLEUM, in *Chemistry*, a fluid substance, resembling in a high degree the essential oils from vegetables. It is of a brownish-yellow colour, of a peculiar odour. Its specific gravity varies from .73 to .878. When exposed to a gentle heat for distillation, the fluid which comes over has less colour, is much thinner, and has more smell. In this state it is called naphtha. It burns with a white flame, and is employed in the vicinity of the Caspian sea for lamps. The earths in these parts are sometimes so saturated with it as to be rendered inflammable.

When it is exposed to the air, even that obtained by distillation, it becomes thick and highly coloured, and puts on the form of bitumen. This no doubt is occasioned by the gradual diminution of its hydrogen, by the oxygen of the atmosphere.

It is soluble in alcohol and ether, and combines with the fixed and volatile oils. It is hence used to dissolve resinous bodies and bitumen, and might, in many cases, answer the purposes of oil of turpentine.

It is found in different states. According as it has had access to the air, it will thicken and become of a darker colour. See NAPHTHA and BITUMEN.

The more fluid petrolea, says Dr. Lewis, have been distinguished by the name of *naphtha*; and the thicker by those of *pissasphaltum* and *pisselaum*.

These, according to all appearance, must be the work of subterraneous fires, which raise or sublime the more subtle parts of certain bituminous matters that lie in their way.

These parts, being condensed into a liquor by the cold of the vaults of rocks, are there collected, and ooze thence through clefts and apertures, with which the disposition of the ground furnishes them.

Petrol, then, is a liquid bitumen, only differing by its liquidity from other bitumens, as asphaltum, jet, amber, and the like substances.

The naphtha, which is either a liquid, or at least a very soft bitumen, is nearly allied to petrol.

Hitherto there has been little petrol found, except in hot countries. Olearius says, he saw above thirty springs of it near Scamachia, in Persia. (See PERSIA.) There are also petrels in the southern provinces of France; but the best are those in the duchy of Modena, first discovered by Ariosto, a physician, in 1640, in a very barren valley, twelve leagues from the city of Modena.

Three canals are there dug with great expence in the rock; by which three different kinds of petrol are discharged into little basins or reservoirs: the first, as white, clear, and fluid as water, of a brisk penetrating smell, and not disagreeable; the second of a bright yellow, less fluid, and of a less brisk smell than the white; the third of a blackish red, of thicker consistence, and a smell more approaching that of bitumen.

There are many varieties of these oils in regard to colour, fluidity, subtilty, and the pungency of their smell, and taste; the most fluid are, in general, the most subtle and pungent. With us they are commonly sophisticated.

Mr. Boulduc made several experiments with the petroleum of Modena, an account of which he gave to the Paris Academy.

It easily took fire on being brought near a candle, and that without immediately touching the flame; and when heated in any vessel, it will attract the flame of a candle, though placed at a great height above the vessel, and the vapour it sends up taking fire, the flame will be communicated to the vessel of heated liquor, and the whole will be consumed. It burns in the water, and when mixed with any liquor, swims on the surface of it, even of the highest rectified spirit of wine, which is one-seventh heavier than pure petroleum. It readily mixes with all the essential oils of vegetables, as oil of lavender, turpentine, and the rest, and seems very much of their nature: nor is this very strange, since the alliance between these bodies is probably nearer than is imagined, as the essential oils of vegetables may have been originally mineral ones, and drawn up out of the earth into the vessels of the plant.

Petroleum, when shaken, yields a few bubbles; but they sooner subside than in almost any other liquor, and the liquor resumes its clear state again almost immediately. This seems owing to the air in this fluid being very equally distributed in all its parts, and the liquor being composed of particles very evenly and nicely arranged.

The extensibility of this oil is also amazing. A drop of it will spread over several feet of water, and in this condition it gives a great variety of colours, that is, the several parts of which this thin film is composed, act as so many prisms.

The most severe frost never congeals petroleum into ice, and paper wetted with it becomes transparent, as when wetted with oil; but it does not continue so, the paper becoming opaque again in a few minutes, as the oil dries away.

Spirit of wine, which is the great dissolvent of sulphur, has no effect upon petroleum, not even with ever so long a digestion. It will not take fire with the dephlegmated acid spirits, as oil of cloves and other of the vegetable essential oils do: and in distillation, either by balneum

Maria, or in sand, it will neither yield phlegm nor acid spirit; but the oil itself rises in its own form, leaving in the retort only a little matter, thick as honey, and of a brownish colour. Whoever, therefore, would use this oil in medicine, must take it as nature has prepared it, art having no power to make any alteration in it. Mem. Acad. Paris, 1715.

It is remarkable, that all the petroleum got from the lake of mount Ciaro in Italy is white, whereas that of Modena is yellow, and that of Parma brown. These wells or holes continue to furnish the oil in different quantities for a considerable time, and, when they will yield no more, they pierce the strata in some other place. Mem. Acad. Scienc. Par. 1736.

The petroleum wells of the Birman empire, situated about five miles E. of Yayuangheoum, or Petroleum creek, on the Irrawaddy, supply the whole empire, and many parts of India, with this useful product. The mouth of the creek, when captain Symes visited it, was crowded with large boats, waiting to receive a lading of oil; and immense pyramids of earthen jars were raised within and round the village, disposed in the same manner as shot and shells are piled in an arsenal. This place is inhabited only by potters, who carry on an extensive manufactory: the smell of the oil is said to have been extremely offensive. (Symes's Embassy to Ava, vol. ii.) Of the wells in this district there are said to be 520, which yield, annually, more than 400,000 hogheads of petroleum.

PETROLEUM *Barbadense*, *Barbadoes tar*, a species of *bitumen*, for an account of which, see BITUMEN. Petroleum is a stimulating antispasmodic and sudorific; and as such it has been given in asthma and coughs, unattended with inflammation, but it is chiefly used for external purposes, as a stimulant in diseases of the hip-joint, rheumatic, and other chronic pains, chilblains, and to paralytic limbs, applied by friction. It is, however, scarcely ever employed in either way, and on this account is not often to be procured in the shops. The dose of petroleum may be from $\mathfrak{m}\mathfrak{x}$ to $\mathfrak{f}\mathfrak{ss}$, in any convenient vehicle. In the West Indies the Barbadoes tar is used both as an internal remedy and an external application, in the same cases.

Phosgene gas

PHOSGENE GAS, in *Chemistry*, a species of gas lately discovered by Mr. John Davy, in his efforts to unite together the carbonic oxyd and the oxymuriatic gases. Some unsuccessful attempts had been made for this purpose by Messrs. Gay-Lussac and Thénard, and afterwards by Mr. Murray of Edinburgh. Mr. Davy accomplished this object apparently without any difficulty. The gases were put in contact and exposed to a bright light for a quarter of an hour; when the mixture was diminished to half its original bulk, and a gas was left, which possessed several remarkable properties. It is composed of equal volumes of chlorine and carbonic oxyd gases, condensed into half their bulk.

It is colourless; and has a strong disagreeable smell. Its specific gravity is 3.669; and 100 cubic inches, under a mean temperature and pressure, weigh 111.91 grains; hence it is by far the heaviest gas at present known. It reddens vegetable blues. It combines with ammonia, condensing four times its bulk of that gas, and forming a peculiar neutral salt. Phosgene gas is decomposed by water, and by most metallic bodies. It is an acid of a very peculiar nature, and deserves a much more complete examination. As this gas has been hitherto produced only by the action of light, Mr. Davy proposed to name it "phosgene." *Phil. Transf. for 1812, part i.*

Phosphorus

PHOSPHORUS, Φωσφορος, formed from φως, *light*, and φέρω, *I bear*, a matter, which shines, or even burns, spontaneously, and without the application of any sensible fire.

Phosphori are either *natural*, or *artificial*.

PHOSPHORI, *Natural*, are matters which become luminous at certain times, without the assistance of any art or preparation.

Such are the glow-worms, frequent in our colder countries; lantern-flies, and other shining insects, in hot countries; rotten wood; the eyes, blood, scales, flesh, sweat, feathers, &c. of several animals; diamonds, when rubbed after a certain manner, or after having been exposed to the

sun or light; sugar and sulphur, when pounded in a dark place; sea-water, and some mineral waters, when briskly agitated; a cat's or horse's back, duly rubbed with the hand, &c. in the dark; nay, Dr. Croon tells us, that upon rubbing his own body briskly with a well-warmed shirt, he has frequently made both to shine; and Dr. Sloane adds, that he knew a gentleman of Bristol, and his son, both whose stockings shone much after walking.

All natural phosphori have this in common, that they do not shine always; and that they never give any heat.

The natural phosphori are either *fossile*, *vegetable*, or *animal*.

The fossile are, though very different in degree, some sorts of earths, white sand, limestones, stalactites, and several other figured stones, island crystals, flints, some species of agates, white arsenic; but no sort of metals, metallic or sulphureous bodies, as jet, amber, except the before-mentioned arsenic.

On the other hand, salts imbibe light, provided they are divested of every metallic principle; otherwise not, though as pellucid as possible. For this reason none of the vitriols will imbibe light; but other salts will though with a considerable difference as to quantity; for sal gem and rock salt imbibe very little; sea salt, if dry, and in crystals, much more; and, in like manner, sal ammoniac, sal catharticum, and nitre yet more. This power is weak in the natron of the ancients, and alum; but brightest of all in borax.

In the vegetable kingdom we find very few phosphori; that of dry rotten wood is weak and not lasting; it appears chiefly upon the edges and inequalities of the surface. But this is most remarkable in the rotten wood of the fir-tree, and some others, where, in the dark, you see shining spots as big as tares; whereas in full light the whole surface appears alike. Some few bars are luminous, but not considerably so; but no fruits, seeds, or their meals. Cotton, and the crystals of tartar, appear very bright, but fine loaf-sugar appears the most luminous of all both without and within; gums and resins retain no light.

There is a vast variety of phosphori in the animal kingdom, such as the bones and teeth; to these may be added the shells of fish, egg-shells, the human calculus, bezoar, and those parts of animals in which the terrestrial principle is very predominant. But where there is a considerable quantity of oily matter, as in the hoofs, horns, and feathers, no light is manifest, or at least in a small degree. Light is visibly retained by the skins of several living animals. Water cannot be made to imbibe light, though ice does exceedingly well, and especially snow.

Beccarius proposes some queries concerning the natural phosphori, of which the first is, in what and how great a light the object ought to be placed? He tried different phosphori, in different degrees of light, and found them imbibe most light from the sun itself; next in quantity when the sky was clear; and the least in foggy weather. These experiments should be made in the open air, and not in a house with the glass-windows shut; because many bodies appear luminous when the light has come directly to them, which will not have that appearance when the light has passed through the glass. He lastly tried what light they would imbibe from very bright flame, and found that alabaster itself, which is saturated more than any substance by the sun's rays, imbibed exceedingly little. The next query is, how long these bodies should remain in the light to be sufficiently saturated? Four or five seconds were found the utmost length of time required for that purpose. The other query is, how long the received light will continue in these phosphori? It does not last the same time in all; but continues more or less, from two seconds to eight, in proportion to the strength of the phosphorus, and the quantity of light received.

But that which, of all natural phosphori, has occasioned the greatest speculation, is the

PHOSPHORUS, *Barometrical*, or *Mercurial*. M. Picard first observed, that the mercury of his barometer, when shaken in a dark place, emitted light; with this circumstance, that in shaking the mercury with rapidity, sometimes above, and sometimes below its equilibrium with the air,

the light was only seen when below it, where it appeared as if adhering to the upper surface.

But this light is not found in the mercury of all barometers; which occasions a great difficulty.

M. Bernoulli, upon examining the circumstances of this phenomenon, invented a solution of the same; he imagines, that upon the mercury's descending, the vacuum in the tube increasing, there issues out of the mercury to fill up this excess of vacuity, a very fine subtle matter, before dispersed throughout the pores of this mineral; and that, at the same time, there enters through the pores of the tube another fine matter: thus, the first matter emitted from the mercury, and collected over its surface, striking impetuously against that received from without, has the same effect with Descartes' first element against the second; that is, it produces the motion of light.

But why, then, is not the phenomenon common to all barometers? To this he answers, that the motion of the subtle matter out of the mercury may be weakened, and prevented, by any heterogeneous matter collected on its upper surface, into a kind of pellicle, so that the light should never appear, but when the mercury is perfectly pure. This reasoning seemed confirmed from the experiments of several barometers, which he made according to this plan; but the Royal Academy of Sciences, repeating experiments with barometers made after the same manner, did not meet with the same success; the light being found in some, but not in others.

M. Homberg, therefore, conjectured, that the difference consisted in the different qualities of the quicksilver: in some, he observed, they used quick-lime to purify it; in others, steel-slings. The mercury, then, rising in the distillation, and passing through the lime, might take away some parts thereof, capable, by their extreme smallness, of lodging in its interstices.

Hence, as quick-lime always retains some fiery particles, it is possible, in a place void of air, where they swim at liberty they may produce this lustre.

Mr. Hauksbee has several experiments on the mercurial phosphorus. Passing air forcibly through the body of quicksilver, placed in an exhausted receiver, the parts were violently driven against the side of the receiver, and gave all round the appearance of fire; continuing thus till the receiver was half-full again of air.

From other experiments he found, that though the appearance of light was not producible by agitating the mercury in the same manner in the common air, yet that a very fine medium, nearly approaching to a vacuum, was not at all necessary.

And, lastly, from other experiments he found, that mercury inclosed in water, which communicated with the open air, by a violent shaking of the vessel wherein it was inclosed, emitted particles of light in great plenty, like little flares.

By including the vessel of mercury, &c. in a receiver, and exhausting the air, the phenomenon was changed; and, upon shaking the vessel, instead of sparks of light, the whole mass appeared one continued circle of light. Farther, if mercury be inclosed in a glass tube, close stopped, that tube is found, on being rubbed, to give much more light, than when it had no mercury in it. When this tube has been rubbed, after raising successively its extremities, that the mercury might flow from one end to the other, one sees a light creeping in a serpentine manner all along the tube; that is to say, the mercury is all luminous. The mercury, being made to run along the tube

Afterwards without rubbing it, was found to emit some light, though much less than before: this proves that the friction of the mercury against the glass, in running along, does in some measure electrify the glass, as the rubbing it with the hand does, only in a much less degree. This is more plainly proved by laying some very light down near the tube, for this will be attracted by the electricity raised by the running of the mercury, and will rise to that part of the glass along which the mercury runs; and it is very plain from this, that what has been long known in the world under the name of the phosphorus of the barometer is not a phosphorus, but merely a light raised by electricity, the mercury electrifying the tube. Phil. Trans. N° 484. See ELECTRICITY and MERCURY.

PHOSPHORI, *Artificial*, are such as owe their luminous quality to some art or preparation.

Phosphori are, it is well known, often produced by art; some are made by the maceration of plants alone, and without any fire; such as thread, linen cloth, but above all paper. The luminous appearance of this last, which is now known to be an electrical phenomenon, is greatly increased by heat. This is confirmed by two experiments; the first is, by exposing the paper, spread upon an iron grate, to the naked fire, yet not near enough to scorch it, and then laying a warm brick thereon to retain the heat; by which means it was observed, that where the paper was not screened by the iron grate, it was most luminous; so that by the lights and shades you might distinguish in the dark the image of the iron grate a considerable time. The other experiment is, the application of the paper to a plate of warm brass; from which, when in the dark, you might very easily, by its being less luminous, distinguish the margin of the paper that had not been warmed by the brass.

However Beccarius, though he acknowledges that paper, after having been made red-hot and cooled again, is an excellent phosphorus, found, that it was much injured by being exposed to the light of the sun. He made experiments to the same purpose with a great variety of substances, mineral, vegetable, and animal; and observed, that the effects were the same, and that the stronger the light was, and the longer they were exposed to it, the more injury they received: and he found also, that the injury they received was lasting.

The same author takes notice also of those phosphori which become so by the assistance of fire; but the fire here spoken of is not great enough to dissolve their constituent parts, but only such as may affect the external parts of their texture, and that but gently; so that the process here mentioned is only drying or roasting. For it is not the watery or the saline parts in bodies which are torrefied, but the oleaginous, with which many vegetables, and most animals abound. The white flesh of animals, such as that of chickens, become a phosphorus by roasting, as well as the tendons; and whatever parts of animals become glutinous by boiling, such as carpenters' glue, isinglass, &c. to these may be added cheese. Bones, though they imbibe light without any preparation, have that property in a much greater degree when burnt, and their luminous appearance is much more lively. But roasting has not this effect upon feathers, hoofs, horns, and only in a small degree on whites of eggs, though the yolk when dry easily became a phosphorus.

The same operation which produces several phosphori from the animal kingdom, gives also several from the vegetable. Thus, by gently roasting gums, as myrrh, gum tragacanth, and others, they appear luminous, though dif-

ferent in degrees; and this light is clear in proportion to the gentle evaporation of the aqueous parts. By this treatment nuts of every kind, pulse, corn, coffee-berries, meal, bread, and wafers, also become phosphori. Turpentine, amber, and some resins, require more fire before they imbibe light; so that you must divest them of their acid, and their light ethereal oil, to make them appear luminous. But here great care must be taken that they boil no longer than from being white they turn yellow; for, if you proceed longer, your labour is lost. Those phosphori produced by torrefaction soon lose their power, which, perhaps, neither time, nor a thorough dissolution of their parts, can deprive the natural ones of. In general, as long as the phosphori gained by torrefaction preserve their power, their light is more sharp and striking, but the natural more weak. Those that are gained by calcination, and Baldwin's phosphorus, seem to possess both the striking light of those gained by torrefaction, and the weaker light of the natural phosphori: the last they preserve a long time, but the former is lost, by degrees, much sooner. The well calcined ashes of plants, or rather their terrestrial parts, remaining after the solution of their fixed salts by washing, and neutral salts, continue phosphori after many years: so that, as far as we can judge, the luminary power which is gained by calcination, though not so intense, continues perpetual; whereas, that gained by torrefaction always decreases, and, in a very little while, is no longer visible. Some, even by this method, continue to imbibe light much longer than others. Gum arabic, which continues longest, lasts six days; bread not one, and coffee only a few minutes. However, at any time, by a fresh torrefaction, you may recover these languid phosphori; in which property they have great likeness to the Bolognian stone, and other phosphori prepared by art.

Almost all bodies, by a proper treatment, have that power of shining in the dark, which, at first, was supposed to be the property of one, and afterward only of a few. How this is brought about is not easy to solve. If we suppose, with some, that the light from a luminous body enters and abides in the phosphori; we shall find somewhat new to admire in light itself. It is no new opinion, that this fluid consists of very fine particles, which are continually darted forth from a luminous body in all directions, with a very great velocity: but it has by nobody been laid down hitherto, that these particles are not dissolved by the violence of their agitation, nor dispersed, nor immediately cease to exist; but subsist still, and adhere to what bodies come in their way, as heat does. If, therefore, the particles of light are not dissolved as soon as they are emitted from a radiant body, but continue some time, what else is required but that we allow its atmosphere to every lucid appearance? If the phosphori shine with a borrowed light, but not with their own, and that only when put in motion, and fired by the rays of a shining body, which some experiments seem to confirm, then other new doctrines will arise. There must be then a hidden, a secret principle in bodies, to be lighted up by this most subtle fire. There will be in the universe a certain perpetual fire from these phosphori; the matter of which, though constantly dissipated by burning, does not waste enough to be obvious to our senses. See Phil. Trans. N° 478. in vol. xlv. art. 17. p. 83. and Beccarii Com. p. 52. 91, &c. See LIGHT, LIGHT from Diamonds, and Bolognian PHOSPHORUS, *infra*.

Of artificial phosphori there are three principal kinds: the first *burning*, which consumes every combustible it touches; the other two have no sensible heat; and are

PHOSPHORUS

called the *Bononian* and *Hermetic* phosphorus, to which class others of a similar kind may be reduced.

PHOSPHORUS, *Burning*, in *Chemistry*, is a simple inflammable substance.

The discovery of this phosphorus was first made in 1677, by one Brandt, a citizen of Hamburg, in his researches for the philosopher's stone. Brandt communicated the secret to one Kraaft, of Dresden, but withheld it from Kunckel; upon which this chemist, knowing that urine was the substance employed, succeeded in his attempts of making phosphorus; accordingly, this phosphorus is commonly called *Kunckel's* phosphorus, after his name. A similar phosphorus was also made by Mr. Boyle, after having seen a piece of it in the hands of Kraaft, who brought it to London in 1679, in order to shew it to the king and queen of England; having been only informed that this phosphorus was produced from some matter belonging to the human body. Kraaft, indeed, told Stahl, that he had communicated the process for making it to Mr. Boyle; but this is such an imputation on the integrity and honour of our English philosopher, as can by no means be admitted on the testimony of a man, who had been treacherous to Kunckel, who traded in the secret of making phosphorus, and after selling it to many persons, published the process for making it in the *Mercure Galant*, for June 1683. Kunckel, and a German chemist called Godfrey Hantzsch, to whom Boyle communicated the method of preparing it, were the only persons who made it in any considerable quantities.

M. Hellot, in his *Memoir* upon this subject, *Ac. Paris*, 1737, enumerates all the processes for making it, that were in use soon after the discovery of it; viz. that published by Mr. Boyle in 1680, in the *Phil. Transf.* N° 196. (see *Phil. Transf. Abridg.* vol. iii. p. 346.); that of Kraaft; that of Brandt, in a collection of experiments and observations of Dr. Hooke, published by Dr. Derham in 1726; that of M. Homberg, in the *Ancient Memoirs* of the Academy, in 1692; and those found in the works of several chemists, particularly of Theickmeyer, Hoffmann, and Niewentyt. However, the operation continued in a great degree a secret till the year 1737, when a stranger came into France, and obtained a reward from the ministry for communicating his process, which was executed by Messrs. Hellot, Du Fay, Geoffroy, and Duhamel. Since the publication of M. Hellot's *Memoir*, the operation has been no longer a secret; though seldom executed, because it was rather curious than useful, and both troublesome and expensive.

The solid phosphorus was formerly prepared from urine in the following manner. Evaporate a good quantity of urine of beer-drinkers to the consistence of honey; cover it up in an earthen vessel, and set it three or four months in a cellar to ferment and putrefy. Mix two parts of sand, or powder of pot-sherds, with one part of this urine, and put it into a retort, fitted to a long-necked receiver, with two or three quarts of water in it. Distil it in a naked fire, in a reverberatory furnace; at first gently; after two hours, augment the fire gradually, till all the black fetid oil be drawn off. Raise the fire to the highest degree; upon which white clouds will come into the receiver, and fix, by little and little, on one side, in form of a yellowish skin; and another part will precipitate to the bottom in powder. Keep the fire thus violent for three hours, till no more fumes arise. Let all cool, and unloose the vessels; and, throwing more water into the receiver, shake all well about, to loosen what sticks to the sides. Pour the whole into a glass vessel, to settle.

The volatile salt will now dissolve in the water, and the

phosphorus and oil will sink to the bottom; then pour off the water, and gathering the remaining part together, put it into a glass vessel, with a little fresh water, and digest it in a sand-heat, stirring it from time to time with a wooden spatula.

By this means, the phosphorus will separate from the oil, and sink to the bottom: pour off the oil, and make up the phosphorus, while hot, into sticks for use.

Boerhaave gives us other ways of preparing phosphorus. Recent urine, he observes, digested three or four days in a tall glass, with a heat no greater than that of a healthy man, grows ruddy, fetid, and cadaverous; this digested urine, being put to distil in a retort, yields a clear, fetid liquor, then a yellow volatile salt, which evaporated to the consistence of a sapo, and mixed with four times its weight of dry sand, and the distillation continued in a covered retort, there successively comes over, by greater and greater degrees of fire, a fetid brown oil, blueish fumes, and, finally, a gross shining matter, which sinks in water, and is the solid phosphorus.

To make it more easily, and to the best advantage, it may be proper to take a sufficient quantity of human urine, afforded by a person not much given to drink wine, and exhale it away in an open vessel to a rob, or the consistence of honey; then set it to putrefy for half a year, and, upon distillation, it will afford a large proportion of salt, after which, if six times its own quantity of sand, or brick dust, be added to the remainder, and the distillation be continued, as in the case last mentioned, the phosphorus will fall into the water. Or it may commodiously be prepared, by suffering the rob of urine to digest for two years in an open vessel in the open air; during which time, a slimy, feculent, unctuous, earthy matter, will fall to the bottom; which, being frequently washed with pure water, wherein it will not dissolve, will leave a white matter behind it, neither of an alkaline, acid, saline, or terrestrial, nor scarcely of an unctuous nature: and this is of itself a proper matter for the making of phosphorus by distillation with sand.

In order to preparing the phosphorus, and indeed most of the other preparations of urine, the first step is to reduce that liquor to the consistence of a rob or thick extract; those who have worked on this subject sufficiently know how abominably nauseous and disagreeable a task this is. The operator alone is not the person who is almost poisoned by it, but the whole neighbourhood is affected; and it is well known, that our Godfrey, who used to prepare large quantities of this substance, was always obliged to keep a house in the fields to perform this part of the processes in.

There is an easy and excellent method proposed by Stahl for the performing of this troublesome business, by means of condensation by cold or freezing. There needs no more than to expose the proper quantity of urine to some frosty nights in winter; or at any time of the year to our ice-houses, or other places where ice is preserved all the year round. The frost will, in this case, affect a large part of the urine, but not the whole; and the liquid part being separated from the solid ice, it will be found that the watery parts alone have suffered the freezing, and that all the unctuous and saline ones are left behind in the unfrozen part, which is, by repeated freezings of its yet remaining aqueous parts, at length reduced to that sort of rob which is required for all the purposes of distillation, and that without any trouble or offensiveness, either to the operator or any body else. The power of condensation by freezing in this manner, extends to wine, vinegar, and all fermented

liquors; but it operates differently on the several different ones, and is to be regulated according to their natures. The natural cold of our climate is seldom too great for any of the liquors we desire to condense; that is, it is never so great as to condense the whole into ice. It often is not sufficiently great to condense the aqueous part, even after ever so many repetitions. In this case, it may be proper to bring in the use of the common freezing mixtures, made with ice, or snow and salt. To suit the artificial degree of cold, in these cases, requires care and experience, and is almost as nice a point as the suiting of the degrees of heat in the operations of chemistry.

In 1743, Mr. Margraaf published, in the *Memoirs of the Academy at Berlin*, a new and excellent process for obtaining more easily and expeditiously, and at less expence than had hitherto been done, a considerable quantity of phosphorus. In his process, a kind of plumbum corneum is previously prepared, by distilling a mixture of four pounds of minium with two pounds of powdered sal ammoniac; the residuum after the distillation, or the plumbum corneum, is to be mixed with nine or ten pounds of extract of putrescent urine, boiled to the consistence of honey. This mixture is to be made slowly in an iron cauldron set upon the fire, and by frequently stirring the contents. Half a pound of powdered charcoal is then to be added, and evaporation is to be continued till the whole is reduced into a black powder, which is to be put into a retort, in order to extract from it, by a moderate and gradual heat, all the volatile products of urine, that is, volatile alkali, fetid oil, and an ammoniacal matter which adheres to the neck of the retort. In this distillation the heat is only to be raised so as to make the matter red-hot. After the distillation a black and friable residuum is left, from which the phosphorus is to be extracted by a second distillation, and a stronger heat. Before it is exposed to another distillation it may be tried by throwing some of it upon hot coals. If the matter has been well prepared, a smell of garlic exhales from it, and a blue phosphoric flame is seen undulating along the surface of the hot coals. This matter is to be put into a good earthen retort, capable of sustaining a violent fire, and which may be secured with a covering of clay and hair. Three quarters of the retort are to be filled with the matter which is to yield the phosphorus. It is to be placed in the common furnace for distillation with a retort; excepting that instead of being terminated by an ordinary reverberatory or dome, this ought to be terminated by the upper piece of an air-furnace, to which a tube is to be applied, the diameter of which ought to be from four to six inches, according to the size of the furnace, and the height from eight to nine feet. This apparatus, which Mr. Beaumé uses, is necessary for raising a sufficient heat, and for the convenience of throwing in a sufficient quantity of fuel through the door of the upper piece of the furnace. The retort ought to be well luted to a receiver of moderate size, pierced with a small hole, and half full of water. For this purpose ordinary fat lute may be bound on with strips of linen, dipped in a lute prepared with lime and whites of eggs. The hole in the furnace through which the neck of the retort passes ought to be well stopped with furnace-earth. Lastly, a small wall of bricks is raised betwixt the furnace and the receiver, to guard this vessel against heat as much as is possible.

All these preparations being made the evening before the distillation is to be performed, we are then capable of proceeding to this operation, which is very easy. The retort is to be heated by slow degrees during an hour and a half; and then the heat is to be increased till the retort be red-

hot, and the phosphorus begin to pass in luminous vapours: when the retort is almost of a white-red heat, the phosphorus passes in drops, which fall and congeal in the water at the bottom of the receiver. This degree of heat is continued till no more passes into the receiver. When a retort contains eight pints or more, this operation continues about five hours.

Mr. Margraaf's apparatus is somewhat different from that above described. He divides the whole quantity of matter from which the phosphorus is to be obtained into six small retorts, which he places in a furnace that he describes. The advantage of this division is, that if any accident happens to one retort, the whole matter is not lost; and as the retorts are smaller, a less heat is required. If, indeed, much phosphorus was to be made, this practice would be safe and excellent; but Macquer affirms, that the method above described of Mr. Beaumé is very convenient when a large quantity of phosphorus is not wanted, and that he has never seen it fail.

Phosphorus does not pass pure in this distillation, but is blackened by soot or coal, which it carries along with it: it may be easily purified, and rendered white and fine by a second distillation or rectification. This rectification is made in a small glass retort, to which is adjusted a small receiver half full of water. A very gentle heat is sufficient, because phosphorus once formed is very volatile: and as the fuliginous matters with which it is soiled were raised merely by the violence of the heat, they remain at the bottom of the retort in this distillation, and the phosphorus passes very pure.

The phosphorus is then usually divided into small cylindrical rolls, for the convenience of using it. This is done by putting it in glass tubes immersed in warm water. This very gentle heat is sufficient to liquefy the phosphorus, which is almost as fusible as suet. It takes the form of the glass tubes, from which it may be taken out when it is cold and hardened. That it may be more easily taken out of the tubes, these must be somewhat of the form of fruitums of cones. All these operations ought to be made under water, to prevent the inflammation of the phosphorus.

Phosphorus is now usually procured by the following process. Calcine a quantity of bones till the whole of their inflammable matter is consumed, which will be indicated by their whiteness. After they are reduced to a fine powder, let 100 parts, by weight, be mixed with 500 parts of water, in a vessel of stone ware, or any other which sulphuric acid will not act upon. To the above mixture add, by degrees, 40 parts of sulphuric acid, constantly stirring the mixture with a stick or a glass rod. After the effervescence has subsided, let the mixture stand for a day or two, then decant off the clear liquor, which is to be preserved. Let the residuum be agitated with a quantity of fresh water, and thrown upon a filtre, adding the clear liquor which runs through to that decanted in the first instance. Let more water be poured upon the filtre till it comes through tasteless. This being added to the last, the whole will contain a super-phosphat of lime, with great excess of acid. In order to separate the phosphoric acid from the lime, the nitrat of lead is to be added. Phosphat of lead precipitates in the state of white powder, while the lime is dissolved in the nitric acid. The phosphat of lead being very ponderous, may be separated by decantation and repeated washing. When the powder is dried, mix it with one-eighth its weight of charcoal powder, and put it into an earthen retort. The common earthen retorts are seldom fitted for this process, being very liable to crack. The clay of which they are formed should be mixed with coarsely powdered cru-

cibles, to render the texture of the substance when baked more open. The outside must be coated with white lead and flint, to form a glazing during the distillation of the phosphorus. Without this precaution the vapour of the phosphorus would escape through the pores of the vessel. The retort, with its contents, must be placed in an air-furnace, with a slit in the side to admit the neck of the retort. The fuel should be well burnt coaks, and the fire raised very gradually. The neck of the retort should be luted to an adapter, which is fitted to a glass receiver, previously filled with azotic gas. A small tube should proceed from another opening in the receiver, terminating in a pneumatic trough. This serves to carry off the elastic fluids which are disengaged in the process. During the first stage of the process carbonic acid is disengaged, which is afforded by the carbon combining with the oxygen of the phosphoric acid and the oxyd of lead. The charcoal always contains a portion of moisture, which is decomposed by the carbon. In the last stage of the process, when the phosphorus rises in the elastic form, a portion of it combines with the hydrogen of the water, forming phosphoretted hydrogen gas, which takes fire when it comes in contact with oxygen of the atmosphere. This spontaneous inflammation of the escaping bubbles, is a certain sign that the phosphorus is coming over. It is seen running down the adapter into the receiver, which contains a small portion of water for it to drop into. The mass which drops into the water is generally of a brownish, and sometimes a darker colour, and consists of phosphorus, containing some carbon, and is otherwise impure. When the apparatus is quite cold, it may be taken out, and placed in a glass funnel provided with a long cylindrical neck, about one-fourth of an inch in diameter, closed at one end with a cork. It is first filled with cold water, so as to cover the phosphorus. The whole is now immersed into hot water, which melts the phosphorus which is caused to occupy the interior of the tube, assuming a pale yellow colour, while that in the top part of the tube is of a darker colour, and contains the impurities. The pure part is broken into pieces, in which state it is sold. If the phosphorus after distillation be very impure, it should be distilled a second time from a glass retort, observing the same precautions in the receiver as in the first process. After this it may be strained through chamois leather under hot water.

The phosphat of lead may also be procured by adding nitrat of lead to urine. The latter substance contains a quantity of the phosphats of soda and ammonia, each of which give up their acid to the lead, forming phosphat of lead, which falls to the bottom of the vessel in the state of an insoluble white powder. This is doubtless the cheapest way of getting phosphorus.

Stahl supposed phosphorus to be a compound of muriatic acid with phlogiston; but it was afterwards proved by the researches of Margraaf, that muriatic acid could not be produced by burning phosphorus, nor could he succeed in forming phosphorus by treating muriatic acid with inflammable bodies. He found in the course of his experiments, what has since led to the overthrow of the phlogistic doctrine. The phosphorus gained weight by burning, and he called the substance resulting from the combustion phosphoric acid. Lavoisier, in a satisfactory manner, confirmed the facts of the above chemist, by burning phosphorus in oxygen gas. The diminution of the oxygen he found just equal to the increase of weight in the phosphorus after burning. Hence it was established, that phosphoric acid was a compound of phosphorus and oxygen.

Phosphorus, when perfectly pure, is of a pale yellow colour, having some resemblance to white wax. Like the

latter substance it softens by heat, and is so ductile as to be cut with a knife.

It is called "phosphorus fulgurans" from its corruscations; and "phosphorus smaragdinus," because its light is frequently green or blue, especially in places that are not very dark.

It is also called "solid phosphorus," from its consistence.

It dissolves in all kinds of distilled oils; and, in that state, is called the "liquid phosphorus."

It may be ground in all kinds of fat pomatums; in which case it makes a luminous unguent.

So that the phosphorus fulgurans, smaragdinus, solid and liquid phosphorus, and luminous unguent, are all the same preparation, under different circumstances. See *FULGURATING Phosphorus*.

The specific gravity of phosphorus is about 1.77; the fusing point is 90° Fahr.; and it assumes the form of vapour at a little short of 600°.

When phosphorus is heated to 148 in the open air, it takes fire and burns with great brilliancy, owing to the rapidity with which it combines with oxygen. Very dense white fumes are produced, so as ultimately to nearly obscure the flame. If the combustion be made in a vessel, the fumes adhere to its sides, and become liquid, by attracting moisture from the atmosphere. A portion of red matter is left after the burning has ceased, which is probably a compound of phosphorus and carbon. The liquid which is formed upon the sides of the vessel has an acid taste, and consists of phosphoric acid, water, and probably a small quantity of phosphorus which has escaped combustion. When phosphorus is burnt in pure oxygen, the light produced is of such dazzling splendour as to give pain to the eyes. The combustion is by this means complete, and if the oxygen is in sufficient quantity, the whole is converted into phosphoric acid.

Lavoisier found that 100 grains of phosphorus took up 154 grains of oxygen, supposing the atom of oxygen to be 7, hydrogen being 1, agreeably to the numbers of Dalton. And considering the phosphoric acid as an atom of phosphorus with two atoms of oxygen, we have $\frac{154}{100} = \frac{14}{9.1}$. Dalton has fixed the atom of phosphorus at 9. From these data the atom of phosphoric acid will be $9 + 2 \times 7 = 23$.

When phosphorus is exposed to the air in small bits, it gives out a white smoke for some time, and is ultimately changed into a clear vivid oily liquid, which has an acid taste. In this process it combines slowly with oxygen, and consists of one atom of phosphorus with one of oxygen, or $9 + 7 = 16$. When phosphorus is made to undergo slight combustion, by melting it over the interior of a phial, with the presence of small quantities of air, the phosphorus assumes a reddish colour. By this change it is found to take fire with much greater facility, so much so that this process is resorted to in the construction of the common fire bottles.

From this and other facts it is probable that an oxyd of phosphorus exists with less oxygen than is contained in phosphoric acid. It doubtless is constituted by 2 atoms of phosphorus to 1 of oxygen, or $2 \times 9 + 7 = 25$. See *PHOSPHOROUS and PHOSPHORIC Acids*.

The action of the acids upon phosphorus is treated under the respective acids, but what has been omitted under *OXY-MURIATIC Acid*, we shall introduce here.

The muriatic acid does not act upon phosphorus when the acid is in the gaseous form, but when presented in combination with some other bodies, it forms very curious combinations, which have been little noticed. We are

indebted to sir Humphry Davy for our knowledge of these facts.

When phosphorus is immersed in oxymuriatic acid gas, it burns with a pale flame, producing a white substance, which adheres to the sides of the vessel. The above chemist found that one grain absorbed nine cubic inches of the gas, and hence concludes that 1 of phosphorus combines with 6.8 of oxymuriatic acid, or, agreeably to the nomenclature of this philosopher, who considers the latter a simple body, *chlorine*. The number he gives to represent one proportion of chlorine is 67, that of oxygen being 15 and phosphorus 20; so that he concludes the compound formed by burning phosphorus in chlorine gas to consist of two proportions of chlorine equal 134, to one proportion of phosphorus equal to 20, or $134 + 20 = 154$, the number representing the compound. To this substance he has given the name of phosphorana. The advocates of the old hypothesis consider this compound as constituted by two atoms of muriatic acid, free from water, united to one atom of phosphoric acid, and agreeably to the common nomenclature it will be called a supermuriat of phosphorus. Dalton's number for muriatic acid is 22, for oxygen 7, and for phosphorus 9. Hence this substance will be constituted by $2 \times 22 + 2 \times 7 + 9$, or 58 oxymuriatic acid to 9 of phosphorus, but in fact 44 muriatic acid to 23 phosphoric acid.

The compound in question is described by its discoverer as being a snowy white substance. It is volatile at a temperature less than that of boiling water. It is capable of being fused under pressure, and then crystallizes in the shape of prisms which are transparent.

He states that "it acts violently upon water, which it decomposes." Its phosphorus combines with the oxygen, producing phosphoric acid, and its chlorine with the hydrogen, forming muriatic acid. The advocates for the old opinion equally well explained the action of water upon this substance, by supposing the same quantity of water to combine with the muriatic acid, which sir Humphry would state to be decomposed.

Another compound of this kind has been discovered by the same chemist, by distilling phosphorus through the powder of corrosive sublimate in a glass tube. A limpid fluid is obtained, which he states to be a compound of one proportion of chlorine with one proportion of phosphorus, or $67 + 20 = 87$. The properties of this compound are stated by sir Humphry as follows: it emits and fumes when exposed to the air, decomposing the aqueous vapour, and is converted into acid in the air without inflammation. In its pure state it does not redden dry litmus paper. The vapour from it burns in the flame of a candle. When poured into water, it is converted into muriatic and phosphorous acid, the hydrogen combining with the chlorine to form muriatic acid, and the oxygen with phosphorus forming phosphorous acid. This solution, being evaporated to the consistence of syrup, affords a very pure phosphorous acid combined with water, the muriatic acid having escaped. It becomes solid on cooling.

Sir H. Davy has called the above compound phosphorana.

By those of the common opinion, this substance is considered as a compound of pure muriatic acid and phosphorous acid. The phosphorus, on passing through the superoxymuriat of mercury, took an atom of phosphorus from the mercury forming phosphorous acid, which, combining with an atom of muriatic acid, formed the compound in question, leaving behind an atom of muriat of mercury (calomel), which consists of an atom of muriatic acid, with an atom of the first oxyd of mercury. By Dalton's numbers this substance is constituted by one atom of muriatic acid, 22

added to one of phosphorous acid, equal to $9 + 7$ or 16, the whole being equal to $22 + 16 = 38$. All the phenomena stated above, which have been explained by sir Humphry's hypothesis, will be equally well explained by the old theory. The above ingenious chemist has pointed out a third compound of chlorine with phosphorus, which he supposes to consist of one proportion of chlorine with two of phosphorus, or $67 + 2 \times 20 = 107$. This, by the old doctrine, would be considered as composed of 1 of muriatic acid, 22 to 2 of phosphoric oxyd, equal 32, the whole being 52.

This substance was first obtained by Guy Lussac and Thénard, by distilling phosphorus and calomel. If its constitution be as above stated, 9 of phosphorus should be distilled with 196 of calomel.

Phosphorus combines with hydrogen, forming a gaseous compound called by some phosphoretted hydrogen, and by others more properly phosphoret of hydrogen. Several circumstances shew the affinity between phosphorus and hydrogen to be very slight, particularly its liability to be decomposed even by agitation with water. The following is the process recommended by Dalton for procuring it. To two ounces of dry hydrat of lime, or lime which has just taken as much water as is required to slack it, add 50 grains of phosphorus in small bits. Let these be put into a glass retort, which has been previously filled with nitrogen gas. Without the latter precaution the presence of oxygen would decompose the gas intended to be obtained. Let the neck of the retort be connected with an hydromuriatic trough, and apply the heat of a lamp, which brings over the gas. The time is here more than is necessary, which is no inconvenience. The absolute quantities which are engaged in the process are, 1 atom of hydrat of lime $= 8 + 24$, and 2 atoms of phosphorus $= 2 \times 9 = 18$. The water of the hydrat of lime is decomposed. The oxygen combines with one atom of phosphorus, forming phosphorous acid, which afterwards combines with the lime. The hydrogen combines with the other atom of phosphorus, forming phosphoret of hydrogen, which comes over in the form of gas. In this state it takes fire spontaneously in the open air, or in contact with oxygen. The phosphorus is easily separated by the electric spark, and even by standing over water, leaving the hydrogen pure, and occupying the original volume of the gas. This latter effect taking place partially, has given rise to the opinion of phosphorus combining with hydrogen in different proportions. We can hence explain the assertion made by sir H. Davy, in which he says he has obtained phosphoretted hydrogen gases of different specific gravities, from 4 to 7; hydrogen being 1.

The composition of this gas is easily inferred from its specific gravity, which Dalton states to be 10.5, hydrogen being 1. Hence if 1 of hydrogen takes up 9.5 of phosphorus without any change of volume, it will make the specific gravity as above. By theory, 9 of phosphorus should combine with 1 of hydrogen, when 1 atom of the former combines with 1 of the latter. We may hence conclude that an atom of this gas in a state of purity is $1 + 9 = 10$.

To confirm this, Mr. Dalton found that 1 measure of this gas to 1.5 oxygen produced phosphoric acid; and 1 measure to 1 produces phosphorous acid. We are indebted to sir Humphry Davy for the discovery of a new compound of phosphorus and hydrogen, which he obtained by exposing the solid hydrat of phosphorous acid to heat in a retort. An elastic fluid is produced, having a less disagreeable smell than the phosphoret of hydrogen, already described. It does not, like the latter, explode spontaneously. When heated to 300° Fahrenheit with oxygen, it detonates with

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violence. It also explodes in oxymuriatic gas with a white flame. This chemist supposes its specific gravity to be about 12, hydrogen being 1.

When heated in potassium, its volume is doubled, and the gas produced is pure hydrogen. When sulphur is sublimed in it, the volume is doubled, and sulphuretted hydrogen gas produced.

He found that 3 in volume of this gas took up more than 5 of oxygen. He concludes its composition to be nearly 2 of hydrogen to 10 of phosphorus, by weight. According to Dalton's numbers it will consist of an atom of phosphorus to 2 of hydrogen, or $9 + 2 = 11$. If its volume be doubled by taking away its phosphorus, which is the case in the experiment with potassium, its specific gravity will be increased by 1 compressed into $\frac{1}{2}$, which will give specific gravity equal to 2: this added to 9, the weight of the phosphorus, will give $9 + 2 = 11$, which is very near to Sir Humphry's experiment. In the experiment where it combines with the sublimed sulphur, the volume is doubled, and two atoms of sulphuretted hydrogen are formed, one of which being equal to the original volume, will make the specific gravity of this gas equal to that of sulphuretted hydrogen, which is about 14, hydrogen being 1. The mean of these will be $\frac{11 + 14}{2} = 12.5$, which comes very

near to Sir Humphry's statement of the specific gravity, and strongly confirms the rest of the facts relative to it.

The oxygen required for its total absorption will be 28 to 11 by weight, and $\frac{28}{11} \times \frac{12}{14} = \frac{24}{11}$, or 2 to 1 by measure nearly. This is obtained by multiplying their ratios of weight by the inverted ratio of their specific gravities.

Phosphorus combines with sulphur by melting them together in a glass tube, from which oxygen is excluded. The compound is more fusible than either of the elements. Sir Humphry Davy found that a compound of these bodies in the proportion of 3 of sulphur to 4 of phosphorus, is fusible at 40° Fahrenheit. When solid, its colour was of a yellowish-white. These bodies, like all others, must produce most complete compounds in certain definite proportions dependent on the ratio of the weight of their ultimate atoms. Atom to atom, their proportions will be 9 to 13. The compound above alluded to will be 2 atoms of phosphorus to 1 of sulphur, or $18 + 13 = 31$. The most remarkable properties possessed by these compounds are their increased fusibility, and their taking fire at a lower temperature than phosphorus. This latter property has been taken advantage of in making the common fire-bottles. Their proportions for this purpose are generally about 2 phosphorus and 1 sulphur. This is nearly 3 atoms of phosphorus to 1 of sulphur, which would be 3×9 to $13 = 27$ to 13.

Dr. Priestley has made many experiments with phosphorus, in different kinds of air; and has found, that it smoked and gave light in the acid air, just as it would have done in common air confined, without being sensibly wasted for twelve hours, and with a very inconsiderable diminution of the bulk of the air; in alkaline air it gave no light and made no lasting change in its dimensions; in nitrous air, it gave no light, nor did it lessen its power by diminishing common air, and the phosphorus remained unchanged; and after having remained a day and two nights in vitriolic acid air, it produced no sensible effect, and gave no light.

Dr. Fordyce has suggested the following easy method of reducing phosphorus to powder: take phosphorus of urine two drachms; put it into a four-ounce phial; pour upon it three ounces of water; heat it gently by immersion in warm water, till the phosphorus melts; shut the phial with a cork;

take it out of the water, and shake it briskly till it be cold; and the phosphorus will be found in powder. A receiver may be lined with this powder by adding a very small quantity of water to it, and then making the powder to adhere to its internal surface, by gently inclining and turning the receiver round. Macquer's Chem. Dict. art. *Phosphorus*, and Priestley's Experiments and Observations on Air, &c. Phil. Transf. vol. lxi. part ii. p. 504, &c.

PHOSPHORUS, Properties of Solid. 1. With this phosphorus one may write on paper as with a pencil, and the letters will appear like flame in the dark; yet, in the light, nothing will appear but a dim smoke. This is occasioned by the oxygen of the atmosphere combining slowly with the phosphorus.

If the letters written with this phosphorus are warmed by the fire, they presently become dark lines, which continue upon the paper like ink.

2. A little piece, rubbed between two papers, takes fire instantaneously, and if care be not taken in the management of it, there is danger of burning the fingers, the phosphorus being exceedingly inflammable.

3. Its burning is very vehement, and penetrates deeper into the flesh than common fire; and it is very difficult to be extinguished.

Dr. Slare, in order to determine whether air contains the pabulum of flame, as some have supposed, placed a large piece of phosphorus in a receiver; but upon exhauing it, he found that it became more luminous, and that upon admitting the air it returned to its former state. This property was also ascertained by several experiments of Mr. Hauksbee.

M. Cassini happening to press a piece in a cloth between his fingers, the cloth immediately took fire; he endeavoured to put it out with his foot; but his shoe caught the flame, and he was obliged to extinguish it with a brass ruler, which cast forth rays in the dark for two months after.

The solid phosphorus ceases to shine and never spoils, provided it be kept in a phial full of water; but if any part of it emerge, it will shine, though the glass be hermetically sealed; and will continue shining in a large glass without water for several days, with very little diminution of its light or weight; and even when immersed in water, it will sometimes make very bright and vigorous corruscations in the air; that in form of an unguent, does not keep so well; and the liquid phosphorus worst of all.

The liquid phosphorus is best made by digesting in horse-dung, a little bit, or some scrapings of the solid kind, for two days, in oil or essence of cloves, oil of turpentine, or the like. After the dissolution, the oil will be so impregnated with it, that, upon opening the bottle, the matter will appear on a flame.

PHOSPHORUS, Experiments with Liquid. By washing the face, hands, or the like, with liquid phosphorus, Dr. Slare tells us they will be made to shine very considerably in the dark, and the lustre thereof will be communicated to adjacent objects, yet without any offence to the skin.

As soon as the candle is brought in, the shining disappears, and no change is perceivable.

This phosphorus emits frequent flashes like lightning, even when close stopped, especially in warm water. Hence Mr. Boyle takes occasion to draw a parallel between lightning and phosphorus. Phil. Transf. Abr. vol. iii. p. 348, &c. Hauksbee's Physico Mech. Exper. p. 122. In some cases animal sweat, which is similar to urine, has been observed to be phosphoraceous, without any preparation. An instance of this kind is related of a person who used to eat great quantities of salt, and who was a little subject to the gout, after sweating with violent exercise. Stripping himself in

the dark, his shirt seemed to be on fire, and a urinous smell was perceived, similar to that which issues from cabbage much salted and strongly fermenting. *Act. Cæsariensis*, vol. v. p. 334.

PHOSPHORUS, Bolognian, or Bononian. The second kind of artificial phosphorus, is a preparation of stone called the Bononian stone, from Bologna, a city in Italy, near which it is found.

The first who undertook to make this stone luminous, was a chemist of that city, called Vincenzo Casciarolo. Poterus, Licetus, &c. have described the process; but mistakenly. M. Homberg, who made a journey to Italy, expressly to learn the preparation, first communicated the same to M. Lemery, who published it in the seventh edition of his chemistry. (See *BONONIAN Stone*.) Under that article, the reader will find some account of the discovery of this stone, and of the method of preparing it. We shall here subjoin some farther particulars on this subject, chiefly extracted from the dissertation of M. Margraaf. The Bolognian stone, he says, is soft, friable, heavy, crystallized, and incapable of effervescing with acids, before it has been calcined in contact with fuel, and with a free access of air. These qualities have induced him to class it among the heavy fusible spars, which, by a preparation similar to that for the Bolognian stone, are rendered phosphoric. After analysing these substances, he concludes that all contain a vitriolic acid, united to an alkaline or calcareous earth. In order to render these stones phosphoric, such of them ought to be chosen as are the clearest, but crystallized, most friable, most heavy, which exfoliate when broken, and which contain no heterogeneous parts. They are to be made red-hot in a crucible, and reduced to a very fine powder in a glass mortar, or upon a porphyry, and not in a copper mortar, which will obstruct the success of the operation. The powder thus obtained, is to be formed into a paste with gum tragacanth, and divided into cakes as thin as a knife. These are to be dried by a gradual heat. An ordinary reverberatory furnace is to be filled to three quarters of its height with charcoal, and the fire to be kindled; upon this charcoal the flat surfaces of the cakes are to rest; and more charcoal is to be placed above them, so as to fill the furnace, which is then to be covered with its dome, the tube remaining open: all the coal is to be consumed, and the furnace left to cool. The cakes are then calcined, and are to be cleaned from the ashes by blowing upon them with bellows. He farther observes, that after this calcination through the coals, if the stones be exposed to a stronger calcination during a full half hour under a muffle, their phosphoric quality will be rendered stronger. *Ac. Berlin*, 1749, and 1750.

This phosphorus has not any sensible heat, and only becomes luminous after being exposed to the sun, or the daylight; in which state it resembles a burning coal, and preserves its light five or six minutes in the dark, especially if the person observing it has been some time in the dark, or has shut his eyes, that the pupils may be sufficiently expanded; during which time the light gradually dwindles; and, to recover the shining, it must be exposed afresh to the light.

PHOSPHORUS, the Hermetic, or Phosphorus Balduini, which makes the third kind, and properly belonging to the same class with the former, is a preparation of English chalk, with aquafortis, or spirit of nitre, by the fire. See *BALDWIN'S Phosphorus*.

This makes a body considerably softer than the Bolognian stone; but it has all the qualities of it. It has its name from its inventor Baldwin, a German chemist, called *Hermes*, in the society of the *Naturæ Curiosorum*; whence

its other name *Hermetic*. It was discovered a little before the year 1677.

This phosphorus of Baldwin is exactly similar to those made with Bolognian stone and phosphoric spars, differing only in the kind of acid which it contains. It is evidently a nitre with a calcareous basis, and in calcination acquires its phlogiston from the nitrous acid, the chalk also containing some of this inflammable principle. It is observed, however, that this is not so good a phosphorus as the Bolognian; it is not so luminous, it does not retain the light so long, it soon loses its virtue, and never recovers it again. *Acad. Par.* 1693, p. 271.

The process for making this phosphorus, though Baldwin gave no direction for it, nor so much as mentioned the materials, was communicated to the Royal Society, in 1679, by Dr. Slare, and published by Grew, in his *Mus. Reg. Soc.* p. 353; and is as follows: Take good firm chalk, ignite it in a crucible, and then powder it; put into a pint, or half a pint of strong spirit of nitre, *cochlearim*, as much of the powdered chalk as will serve well to satiate it, *i. e.* till it becomes sweetish, and makes no effervescence upon the injection of the chalk. Then dilute this liquor with fair water, filtre it through a paper, and so evaporate it in a large glass, or glazed vessel, or good Hessian crucible, to a dry salt. The preparation may be performed in four hours.

To this class we may also refer some other phosphori, enumerated in the sequel of this article. As the

PHOSPHORUS, Ammoniacal, composed of sal ammoniac and lime, which Mr. Homberg first discovered.

The method of preparing it is this: Take one part of sal ammoniac in powder, and two parts of lime extinguished by lying in the air: mix them exactly together and fill a crucible with the mixture; set it in a small melting heat. As soon as the crucible grows red-hot, the matter in it will melt, and it must be stirred with an iron rod, lest it swell over the edges of the crucible: as soon as the whole is melted, pour it into a copper basin; it will appear of a greyish colour and vitrified, and if it be struck upon with any hard body, there will be seen a fire all over the place where the blow was given. As this matter is brittle, however, and the same mass will not serve often for the experiment, the best method is to dip iron rods in it while melting, and these will be covered with the matter, and will answer the purpose easily and often. *Mem. Acad. Par.* 1693.

This is a combination of quick-lime with the acid of sal ammoniac.

PHOSPHORUS, Antimonial, is the name of a substance having the qualities of the phosphorus discovered by Mr. Geoffroy, in his experiments on antimony. This gentleman had prepared a soap from pot-ashes, quick-lime, and oil, with which he made several experiments on antimony; among others, he was desirous, by means of this, to reduce some diaphoretic antimony, which he had before made from two parts of the regulus of antimony, and three parts of nitre; but, instead of the reduction which he was labouring after, his operation afforded him a much more singular phenomenon: the result of them being a phosphorus, which he had never thought of; a matter which, after having remained perfectly quiet while close stopt down, took fire as soon as ever it was exposed to the air; and that with a violent detonation, and darting every where a shower of fire.

It is easy to see, that there are in the preparation all the requisites for such an effect; nitre, charcoal furnished by the burnt soap, and sulphur both from the soap and from the regulus of antimony; and to all these a sort of calx,

either from the soap, or from some earthy parts of the antimony. It is easy to conceive, that all these substances, coming into a mixture together, should be ready to catch fire and blaze, upon a proper application; but it is not less difficult to account for the effects being produced merely by the air, after the whole had been for a long time in a state of rest.

The method of preparing this new species of phosphorus is this: Mr. Geoffroy mixed two ounces of his soap with one ounce of this diaphoretic antimony; this mixture, being put by little and little into a red-hot crucible, took fire, and swelled very much; after it had done flaming, the mass subsided, and became a red or fire-coloured substance, of an even surface, but still throwing up a vast quantity of blueish-green luminous vapours; and all this regularly happened on every fresh throwing in of the matter, without the least variety. When the whole quantity was thrown in, and had ceased to give any flame or luminous vapour, it remained in the crucible in the form of an inverted mushroom, being hollow, very porous, and of a black colour. When the crucible was taken out of the fire, the edges of this substance were beaten down into the middle, and the whole covered with an ounce of fresh soap; when this last soap was burnt, and a small blueish flame appeared upon the surface of the mass, the crucible was covered with a lid, and a large quantity of charcoal laid upon it, and the fire blown up very briskly by an hundred blasts of the bellows, or thereabouts; but, notwithstanding the fierceness of the fire, there was no fluid scoria formed, but the whole mass remained spongy and porous; the fire was then suffered to go out, and the crucible placed in the corner of the laboratory at rest for five hours. In the evening, when the crucible was perfectly cold, Mr. Geoffroy went to examine the matter, and a servant went to uncover the mass, by removing its surface with an iron instrument; but the moment the air was admitted, the whole mass took fire, burning with a very considerable noise, and darting its flames every way to a great distance.

Mr. Geoffroy repeated the process several times, and always with the same success, whether he used his own diaphoretic antimony, or that made in the common manner. The great caution to insure the success, seems to be taking care of not carrying the fire too far before the addition of the last quantity of soap. *Mem. Acad. Scien. Par.* 1736.

Phosphorus of the Bern-stone, is a name given to stone (which, when heated, becomes a sort of phosphorus) from Bern, in Switzerland, the place where it is found.

This substance was sent to the members of the Royal Academy at Paris, by M. Bourguet, and referred by them to the examination of M. du Fay, whose account of it is published in *Mem. Acad. Paris*, 1724.

The Bern-stone is of a moderate hardness, considerably pellucid, and usually colourless, or whitish, though sometimes with a tinge of green, yellow, or some other colours: it is composed of a number of plates or flakes, laid over one another in the manner of the island crystal; and, therefore, like that body is plainly a spar. It breaks into several faces, and has different angles; but of a somewhat determinate measure, the acute ones being of sixty degrees, and the obtuse ones of one hundred and twenty.

This stone, when heated at one of its angles with the flame of a lamp or candle, splits by means of the flame's insinuating itself into the interstices of the plates that are less firmly united; and these separate, and some fragments usually fly off with considerable violence. One of these pieces, carried into an obscure place, appears surrounded

with a blue flame, which lasts about a minute. And it is to be observed, that these pieces which fly off have all the shape of an irregular pyramid, with an uneven base. If this stone be put into a crucible and surrounded with coals, it becomes a very beautiful phosphorus. The whole bottom of the crucible is seen, even though it be in broad daylight, shining with a bright and beautiful bluish white; and if it be carried into a dark place, the light is seen much more beautifully. If, after it is cold, it be again heated in a crucible, in the same manner, it shews the same bright appearance. After this, if it be tried a third time, it does not shine at all. According to all these phenomena, the effects of fire upon this stone seem to depend on a sulphur contained in it, probably of the same nature with that which enters the composition of the metals. This may, by means of a heat, such as that given by the candle or in the crucible, disengage itself so far from the body of the stone as to take fire; and when it has burnt so long as to consume itself, the luminous property of the stone seems to cease.

The coloured gems are crystals of a peculiar kind, tinged with what has been called the sulphur or phlogiston of metals: this sulphur gives them their colour, and consequently it ought to give them the properties of the Bern-stone, if it were not too fixed to be dissipated in the same easy manner, and to take fire in the dissipation. And it appears, on trial, that the ballard emeralds of Auvergne and other places, the matrix of the amethyst, the fragments of some of the accidental jaspers, the hyacinths, and some sort of rubies, are all phosphoruses of the nature of the Bern-stone, but with different degrees of brightness. The mother of the emerald, the yellow jasper, the water sapphire, the malachite, the opal, and the garnet, have none of them any of this property.

Since the same sulphurs, which take fire in the Bern-stone, are what give colour to these other stones, it should seem, that those, which are not of this phosphorus kind, nor give a light after being heated, should not lose their colours in the fire; and this is found to be true in the garnet, which does not lose any part of its colour, nor is it at all luminous; whereas the hyacinth, and some of the jaspers and other stones, which lose a part of their colour, not the whole, in the fire, become also in part luminous, or more so, in degree, according to the quantity of colour which they lose. This, however, is no certain rule, since the mother of the emerald, the topaz, and some other stones, lose all their colour, and yet are not at all luminous. The reason of this seems to be, that the sulphurs are driven out of these stones so slowly, and in such minute quantities, that they are not at any time collected into body enough to be capable of flame. There is nothing to be objected as to the Bern-stone shining; though they are usually white, they may possess no smaller portion of sulphurs than the coloured stones; only in those the sulphurs may be colourless, or white in themselves. It may be possible also, that the sulphurs in a stone of this kind may be dispersed in such small molecules, as not to form a body sufficient to give any colour; but when collected, in order to be driven off in the fire, they may then be sufficient in quantity to give a blue tinge to the flame.

The island crystal, which is also a species of spar, and which greatly resembles this Bern-stone in many particulars, lies to pieces also in the same manner, on being heated; and when carried into the dark, this also gives some sparks of light, but they are few in number, and loosely scattered over the surface: when this stone is burnt a little in the crucible, there is some small appearance of flame, with a

smell of sulphur, and the matter in the bottom of the crucible is found shattered to pieces; but all the pieces are regular parallelopipeds, as was the original mass.

It is to be observed, that the Bern-stone, and others of the same kind, which only shine in the dark, and that only for a few minutes, when first taken out of the fire, are, properly speaking, endued with no other luminous quality than that of a burning coal; but their light, having been generally unobserved, and requiring darkness to shew it, has obtained for them the specious title of *phosphori*.

PHOSPHORUS, *Canton's*, is an artificial phosphorus, the method of preparing which was discovered by the late ingenious Mr. Canton, and published in the *Phil. Trans.* for 1768, vol. lviii. p. 337, &c.

This is much superior to any single natural substance, and has the advantage of being very easily and cheaply prepared. The process is as follows: calcine some common oyster-shells, by keeping them in a good coal fire for half an hour; let the purest part of the calx be pulverized, and sifted; mix with three parts of this powder one part of the flowers of sulphur; let this mixture be rammed into a crucible of about an inch and a half in depth, till it be almost full; and let it be placed in the middle of the fire, where it must be kept red-hot for one hour at least, and then set by to cool: when cold, turn it out of the crucible, and cutting, or breaking it to pieces, scrape off, upon trial, the brightest parts; which, if good phosphorus, will be a white powder, and may be preserved by keeping it in a dry phial with a ground stopple. The quantity of light which a little of this phosphorus gives, when first brought into a dark room, after it has been exposed for a few seconds, on the outside of a window to the common light of the day, is sufficient to discover the time by a watch, if the eyes have been shut, or in the dark, for two or three minutes before. By this phosphorus celestial objects may be very well represented; as Saturn and his ring, the phases of the moon, &c. if the figures of them, made of wood, be wetted with the white of an egg, and then covered with the phosphorus. And these figures appear to be as strongly illuminated in the night, by the flash from a near discharge of an electrified bottle, as by the light of the day. This phosphorus receives no injury from being exposed to the direct rays of the sun, which is the case of some of the more delicate kinds, as Beccarius has remarked, and Lemery supposed with all. However, it cannot be exposed to moisture without losing its property of imbibing and emitting light, and also its whiteness. Mr. Canton found, that it was more affected by mixture with spirit of wine than with ether. It had been long known, that heat promotes the expulsion of the light, which has been formerly imbibed by these phosphori. Mentzel, who wrote soon after the discovery of Baldwin's phosphorus, asserted, that it had the property of becoming luminous by heat only; the same fact was observed by M. du Fay; but the principle on which it depended was discovered by Beccarius, M. Margraaf, and Mr. Canton, independently of one another. Beccarius was first of opinion with Mentzel, that the light was produced by heat; but finding by repeated trials, that, without previous exposing to the light, heat had no effect, he relinquished that opinion. M. Margraaf fell at first into the same mistake with Beccarius; but he afterwards observed, that the phosphorus would not shine by being placed upon a hot furnace, unless it had been exposed to the light two or three days before. Upon the whole, he concludes, that the light is held in this substance by attraction, and afterwards expelled by heat. Mr. Canton also, without any knowledge of the observations of Beccarius

and Margraaf, found by a variety of experiments, that, when his phosphorus had imbibed light, and had emitted all that it could in the common state of the atmosphere, it would emit more upon the application of heat, but that a continuance of the same degree of heat would only make it luminous for a certain time. Whence he infers, that there is a strong attraction between light and the particles of natural bodies: and that the strong vibrations into which heat throws them, compels them, as it were, to quit their hold of each other; and the light, which this phosphorus gives, by being heated to a certain degree, appears to be caused by its throwing off adventitious particles, and not by any of its own; since its light will decrease, and be entirely gone, before the phosphorus be hot enough to shine of itself, or to emit particles of light from its own body. Lemery and Muschenbroeck have observed, that the Bolognian phosphorus imbibes less light when hot than cold; because it appears less bright when carried into a dark room; but this circumstance is accounted for by Mr. Canton, by its parting with its light faster when hot than when cold, and, therefore, parting with more in the time of the conveyance from one place to another: and this, he also says, seems to be the cause why the Bolognian phosphorus never appears so bright after it has been illuminated, and, consequently, in some measure heated, by the direct rays of the sun, as after it has been only exposed in the shaded open air to the common light of the day. However, there is reason to imagine, that the same degree of heat, which disposes the phosphorus to throw off the light after it has been imbibed, must likewise render it indisposed to receive it. For an account of the result of Mr. Canton's experiments on this substance in favour of the materiality of light, see *LIGHT*.

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The colour of the light, in most phosphori that have been presented to the light, and that are then carried into the dark, is white or reddish-white; but in Wilson's phosphorus, not only white colours, but all those of the prism make their appearance, sometimes being all united in a

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Pier

PIER, in *Building*, derived from the French *pierre*, a *stone*, denotes a mass of stone, &c. opposed, by way of fortress, against the force of the sea, or a great river, for the security of ships that lie at harbour in any haven, such are the pier of Dover, described by Camden Brit. &c., the pier of Ramsgate, and the haven pier of Great Yarmouth, mentioned 22 Car. II.

PIERS are also used in *Architecture* for a kind of pilasters, or buttresses, raised for support, strength, and sometimes for ornament.

PIERS, *Circular*, are called *massive columns*, and they are with or without caps, and are frequently seen in Saracenic architecture.

PIERS of a *Bridge*. See BRIDGE.

M. Belidor observes that, when the height of the piers is about six feet, and the arches are circular, it is sufficient to

make their thickness the sixth part of the width of the arch, and two feet more; but when the arches become of a great span, the thickness of the piers may be reduced to the sixth part; but then the depression of the two feet doth not take place at once; that is, in an arch of above forty-eight feet, three inches are taken off for every six feet of increase of the width of the arch. The thickness of the piers supporting elliptic arches is greater than in the former proportion: thus, in an arch of seventy-five feet wide, the thickness of the pier, whose height is about six feet, should be 13.5 when the arch is circular, and fifteen feet when it is elliptical.

The same author makes the abutments one-sixth part more than the piers of the largest arch.

Mr. Muller has calculated the following table, containing the thickness of the piers of bridges.

TABLE containing the Thickness of the Piers of Bridges.

	6	9	12	15	18	21	24
20	4.574	4.918	5.165	5.350	5.492	5.610	5.698
25	5.490	5.913	6.216	6.445	6.645	6.801	7.930
30	6.386	6.816	7.225	7.513	7.746	7.939	8.102
35	7.258	7.786	8.200	8.532	8.807	9.037	9.233
40	8.404	8.691	9.148	9.523	9.835	10.101	10.328
45	8.965	9.579	10.077	10.489	10.837	11.136	11.394
50	9.805	10.454	10.987	11.435	11.817	12.146	12.434
55	10.640	11.245	11.882	12.364	13.019	13.149	13.218
60	11.400	12.110	12.718	13.281	13.723	14.109	14.314
65	12.265	13.025	13.648	14.185	14.654	15.082	15.433
70	13.114	13.869	14.517	14.049	15.573	16.011	16.400
75	14.000	14.705	15.336	15.965	16.480	16.940	17.354
80	14.747	15.542	16.234	16.842	17.381	17.864	18.298
85	15.513	16.328	17.041	17.674	18.237	18.742	19.194
90	16.373	17.102	17.929	18.578	19.157	19.679	20.152
95	17.184	17.826	18.772	19.438	20.036	20.577	21.068
100	17.991	18.848	19.610	20.293	20.908	21.466	21.976

The first horizontal line expresses the height of the piers in feet, from 6 to 24 feet, each increasing by 3: the first vertical column, the width of arches from 20 to 100 feet, for every 5 feet.

The other columns express the thickness of piers in feet and decimals, according to the respective height at the head of the column, and the width of the arch against it in the first column.

Rectangular piers are seldom used but in bridges over small rivers; in all others they project from the bridge by

a triangular prism, which presents an edge to the stream, in order to divide the water more easily, to prevent the ice from sheltering there, as well as vessels from running foul against them. This edge is terminated by the adjacent surfaces at right angles to each other at Westminster bridge; but those of the Pont-royal, at Paris, make an acute angle of about 60° . However the French, in their later constructions, make this angle to terminate by two cylindric surfaces, whose bases are arcs of 60 degrees. Muller's Pract. Fortif. part iv. sect. 1. p. 257. &c.

Piles

PILES, in *Hydraulic Architecture*, are beams of timber, or stakes of wood, driven firmly into the ground, for various purposes; as, for forming a first foundation for buildings, piers of bridges, &c.; in which cases they are driven quite down into the ground, or are cut off level with its surface, with a view of obtaining a solid bearing for the weight of the structure which is to be raised.

Amsterdam, and some other cities, are wholly built upon piles. The stoppage of the breach in the banks of the Thames at Dagenham, was effected by dove-tail piles; that is, by piles mortised into one another by a dove-tail joint.

Piles are not employed for foundations unless the ground is suspected to be unfound, or when the weight to be borne is exceedingly great. They act to make the foundation solid, by reaching deep into the earth, down to a more substantial stratum, than that of the surface. Indeed, the manner of fixing the piles, by driving them by repeated blows of a powerful machine till they will go no farther, ensures that they come to a good bearing. There are instances of piles being driven down twenty-five feet, before they were thought sufficiently firm.

Piles are also used for making the faces of wharfs, banks of rivers, piers for the sea, &c. For these purposes they are driven in rows, but only a sufficient depth in the earth to make them stand firm, and support the planking or framing which is fixed against them. These piles are usually driven rather in an inclined position. For temporary defence against the water, in laying the foundation of bridges, &c. piles are always required. They are employed in different ways to form an enclosure, or water-tight wall, called a coffer-dam, round the area where the work is to be laid, and from which space the water is drawn by pumps. This is the most difficult of all kinds of piling; because it must stand a great height above the ground, have sufficient strength to resist the pressure of water, and be perfectly close and tight. In navigable rivers detached piles are driven, and very firmly fixed, to mark the enclosures where barges are to lay, and to fender off others from them, as well as to moor them to.

Piles are in general formed of a square timber, tapering if the tree happens to be so, cut to a sharp point at one end, and shod with iron to enter the ground. The other end was bound by a strong iron hoop, to prevent the pile head splitting by the violence of the blows which drive it down. When they are to be driven quite below ground, small trees, if sufficiently straight, may be used without squaring; but for coffer-dams square piles are always used, except that for filling up a row between such square piles. When they are to touch each other, flat ones, called pile planks, are used; they are three or four inches thick, according to the depth of water, and have grooves formed in their adjacent edges, to receive tongues or slips of wood, which make the joints quite tight. To enclose an area for a coffer-dam, two rows or walls of piles are usually driven one within the other, at a distance usually equal to the depth of water they are driven in, or if the current is rapid, once and a half. The space

between these is filled with clay, so as to form a mound or rampart of clay, defended on the outside and inside by wooden walls of piles. To make these walls, large square piles are first driven at a distance of ten or twelve feet asunder, in the line of the intended range of the dam; horizontal tie beams are then extended from one pile to the next, on the inside, each tie being notched into the piles, so that its outer edge is in a line with the inside of the groove for the plank piles, which are to be driven down to fill up the spaces between the piles, and will be guided by these ties to stand exactly vertical, and in a straight line. The first plank piles are begun to be fixed adjacent to the main piles, and thus they proceed from both ends of the space between the piles, till the planks meet in the centre, where the last plank is inserted, and being formed rather wedge-like, makes all the rest tight. The pile planks are cut inclined, or wedge-like on one side only, to form the point, by which means the point is the line of one of the edges of the plank. When a plank pile is to be driven adjacent to another, this edge is applied to the one already fixed, and then as it is driven, the inclined or wedge-like edge entering the ground, causes the pile to approach, and press very close to its neighbour, and it is chiefly by this means they are made to fit water-tight. The fillets are made by spiking a ledge or ruler of wood fast upon the edge of one plank, and a groove of corresponding depth and width is ploughed in the edge of the adjacent plank to receive it. Many different machines are used to drive piles into the ground; some of them are worked by a great number of men, who raise a heavy weight a small height, and let it fall upon the pile, till, by reiterated blows, they drive it to the required depth. The machine employed is extremely simple. A long thick plank of wood is fixed up close to the pile, having a mortise through the upper end, in which a pulley is fitted; a rope goes over this to suspend the rammer, which is a large block of hard wood, properly hooped, to prevent it from splitting. In rising and falling, it slides against the face of the plank, and is guided by irons, which are fixed to the ram, and are bent round the edges of the plank in the manner of hooks. The plank, when placed upright, is secured by guy ropes, in the manner of the mast of a ship; the end of the great rope which suspends the ram, has ten or twelve small ropes spliced into it, for as many men to take hold, and work it by; they raise the ram up two or three feet by pulling the ropes all together, and then letting them go, the ram falls upon the pile head. When the pile becomes firm enough to cause the ram to rebound, they take care to pull the ropes instantly after the blow, that they may avail themselves of the leap it makes.

This is the simplest form of the machine. Others, instead of a plank, have two upright beams attached together, at such a distance asunder, as to leave an opening between them, for the reception of a piece of wood which is affixed to the ram, and by this means it is guided. Instead of guy ropes,

these are usually fixed upon a base, consisting of a triangular frame, upon one angle of which the uprights are erected; and from the other two angles, braces arise, which are so inclined as to reach the uprights at half or two-thirds of their height to steady them. This plan is very convenient for driving piles in corners; but for driving rows, it is more advantageous to have the uprights fixed at the middle of one side of the triangular base, and have stays from all the three angles. A machine of this kind, with a ram of beech four feet long and one foot square, may be worked by ten or twelve men, at the rate of twenty-four blows *per* minute, and fixes the pile very quickly.

To estimate the force of the rammer made use of to drive piles, its weight ought to be multiplied into the velocity it acquires in falling. Thus, if a rammer which weighs 500lb. be let fall from four feet, it will fall that height in half a second, and have at the time of percussion a velocity capable to carry it uniformly eight feet in half a second, without any farther help from gravity; so that we must multiply 500 by 16, or its weight by the number of feet it would fall in a second, and the product 8000 gives the momentum of the stroke. If a capstan, pullies, or windlafs, be made to raise the rammer to a considerable height, and then, by an easy contrivance, loosen it at once from its hook, the momentum of the stroke will always be as the square root of the height from which the rammer fell.

Notwithstanding the momentum, or force of a body in motion, is as the weight multiplied by the velocity, or simply as its velocity, when the weight is given or constant; yet the effect of the blow will be nearly as the square of that velocity; the effect being the quantity the pile is driven into the ground by the stroke. For the force of the blow, which is transferred to the pile, being destroyed in some certain definite time by the friction of the part which is within the earth, which is nearly a constant quantity, and the spaces in constant forces being as the squares of the velocities; therefore, the effects which are those spaces sunk, are nearly as the square of the velocities, or, which is the same thing, nearly as the heights fallen by the ram or hammer to the head of the pile. See upon this subject Leopold, Belidor, also Desaguliers's Exper. Philos. vol. i. p. 336, and vol. ii. p. 417, and Philos. Transf. 1779, p. 120.

For large works, such as bridges, &c., the piles are driven by a different kind of machine: this has a very heavy iron ram, with mechanical powers, by which it is raised to a considerable height, and then let fall, instead of continually repeating small blows. These are sometimes worked by horses, or steam-engines: see elevations of one, in *figs. 1. and 2, Plate XXXV. Mechanics.* A, A, are the uprights, erected on the frame B, and supported by the braces C; they are connected by the cross-fee a at bottom, and the piece D at top; in this the pulley b for the rope d is fitted. Fillets of iron are fixed within side the uprights A, A, and enter grooves made in the edges of the great iron ram E, which is thereby guided as it rises and falls: F is a piece, called the follower, (see *figs. 3 and 4.*) it is a wooden block, sliding between the uprights, and mortised to receive the iron tongs e, which take hold of an eye upon the top of the cast iron ram: the rope is attached to the follower by an iron loop f, through which the centre pin of the tongs passes. On the base, a B, of the machine an iron frame is bolted, to contain the windlafs G, on which the rope d winds. On the end of the windlafs a cog-wheel, g, is fixed, and a pinion upon the axis, h, engages its teeth. Motion is given to the spindle b by the winches k, fixed on each end of it, and the fly-wheel, l, regulates its motion, when turned by two men at each handle. The pile is of course included in the space between the two

uprights, A, A, before it is driven down; and the ram, being engaged by the tongs e, is drawn up by turning the handle, k, till the tails, n, of the tongs come to the inclined planes m, *fig. 1*: by these they are closed together, which opens the lower ends, disengages them from the eye of the ram, and it falls upon the head of the pile immediately. The men at the handles shift the spindle b endways, which dis-unites the pinion from the wheel, and then the weight of the follower, F, runs back the windlafs G, and descends till its tongs take hold of the ram, ready to take it up again. The inclined planes, m, are not fixed to the uprights A, A, but are connected together by pieces of wood, which embrace the uprights, and these have holes through them to receive iron bolts, which also pass through the uprights. By this means the inclined planes can be shifted, to set them at any required height, that they may, by discharging the ram at the proper height, give a blow proportioned to the pile which is to be driven by it. The tongs are sometimes made with rollers in the ends n, n, as shewn in *fig. 12*, that they may act more easily in the inclined planes. Other machines have a kind of latch, shewn in *fig. 11*, instead of the tongs; in this f represents the iron loop for the rope; the centre pin of it passes through the latch r s t, which catches the eye of the ram by the hook t, and is discharged by the line r, when the men snatch it. The weight s is to cause the hook to catch; the loop f is attached to a wooden follower, which guides it between the uprights.

Machines of this kind are frequently actuated by steam-engines. A pulley, which is fixed on the end of the spindle b, in place of the handle k, receives an endless rope from some wheel put in motion by the engine; one man then attends it, to throw the spindle endways at the proper time, to permit the descent of the follower; but we have seen one in which levers, and a connecting rod from the inclined plane, m, were used to disengage the spindle the moment after the follower discharges the ram; by adopting these means much expence of labour would be saved, as the same steam-engine which is afterwards to be employed in pumping out the water of the coffer-dams, would drive the piles for them and the foundations.

The piles of the works of Westminster-bridge, whilst it was building, were driven by a horse-machine invented by Mr. Valoue. A pair of the uprights, such as represented at *figs. 1 and 2*, but thirty feet high, were erected at one end of a frame, which supported a vertical shaft, turned round by the horses, and the framing was of course large enough to admit a circular walk of sufficient size for them to work in, when they drew the ends of arms or levers projecting from the vertical shaft. The whole was erected upon a platform, which was built over a barge in the manner of a deck. The vertical shaft had a wheel or drum upon it, to wind up the rope of the follower, and it was in the construction of this part that the invention lay. A section of the upper part of the vertical shaft and drum is given in *fig. 8*, and a plan in *fig. 9*. Here A is the great upright shaft, or axle, turned by the horses attached to the levers, which are not shewn. The cog-wheel, B, turns the pinion X, having a fly, O, at the top to regulate the motion, and to act against the horses, and keep them from falling, when the heavy ram is disengaged to drive the pile down into the earth in the bottom of the river. The drum, C, is loose upon the axle of the shaft A, but is locked to the wheel, B, by the bolt Y. On this drum the great rope, H, is wound, one end of it being fixed to the drum, and the other to the follower, passing over proper pulleys. In the follower are contained the tongs, which take hold of the ram, by the staple for drawing it up, in the same manner as described in *fig. 2*;

D is a spiral, or fufee fixed to the drum C, on which winds the small rope T: it goes over a pulley, and has a small counterpoise hung to the end of it, which hinders the follower from accelerating as it goes down to take hold of the ram; for as the follower tends to acquire velocity in its descent, the line, T, winds downwards upon the fufee on a larger and larger radius, by which means the counterpoise acts stronger and stronger against it; and so allows it to come down with only a moderate and uniform velocity. The bolt, Y, locks the drum to the great wheel, being pushed upwards by the small lever 3, which passes through a mortise on the shaft A, and turns upon a pin; the lower end of the bolt is guided by passing through a piece of wood, 6, fixed into the great shaft, and the upper passes through an arm of the wheel; the lever, 3, has a weight, 4, which always tends to push up the bolt, Y, through the wheel into the drum; G L is the great lever, turning on the centre m, and resting its end, G, upon the forcing bar 5, which goes down through a hollow in the shaft A, and bears upon the little lever 3. The other end of the lever, L, is long enough to reach to the uprights, and has there a small rope, extended from the end of it up to the inclined planes, so that the follower, when drawn up to the highest, draws this rope, and raises the long end, L, of the lever, depressing the other, and the forcing bar 5. By the horses going round, the great rope, H, is wound about the drum C, and the ram is drawn up by the tongs in the follower, till they come between the inclined planes, which, by shutting the tongs at the top, open them below, and so discharge the ram, which falls down between the uprights upon the pile, and drives it by a few strokes as far into the ground as it can go, or as is desired; after which the top part is sawed off close to the mud, by an engine for that purpose. Immediately after the ram is discharged, a piece upon the follower takes hold of the rope, which raises the end, L, of the lever L G, and causes its end, G, to descend, and press down the forcing-bar, 5, upon the little lever, 3, which by drawing down the bolt Y, unlocks the drum, C, from the great wheel B; and then the follower being at liberty, comes down by its own weight to the ram; and the lower ends of the tongs slip over the eye of the ram, the weight of their heads causing them to fall outwards, and fasten upon it; then the weight, 4, pushes up the bolt, Y, into the drum, which locks it to the great wheel, and so the ram is drawn up as before.

As the follower comes down, it causes the drum, C, to turn backward, and unwinds the rope from it, while the horses, the great wheel, pinion X, and fly, go on with an uninterrupted motion; and as the drum is turning backward, the counterpoise is drawn up by its rope, T, winding upon the spiral fufee D.

There are several holes in the under side of the drum, and the bolt, Y, always takes the first one that it finds, when the drum stops by the falling of the follower upon the ram, till which stoppage the bolt has not time to slip into any of the holes. But the same effect is more certainly produced by a crooked lever, *t*, *fig. 9*, fixed on the framing R, over the end of the vertical shaft; one end of this has a roller, which is pressed upon by the great rope, H, the other end holds down the catch, 5, of the forcing-bar, but as soon as the great rope slackens, it retires, and gives liberty to the small lever, 3, to push up the bolt. As long as the great rope has a tension upon it, to support the weight of the ram or follower, the crooked lever is kept in close contact with the forcing-bar, and when that is depressed, (to discharge the bolt Y,) by locking over its catch, 5, the crooked lever keeps it down, till the follower touches the

ram; the great rope then slackens, and the spring, *v* H, discharges the crooked lever from the catch of the forcing bar, and gives liberty to the small lever, 4, to push up the great bolt, and to lock the drum to the great wheel, and the ram is drawn up again as before.

The peculiar advantages of this engine are, that the weight of the ram, or hammer, may be raised with the force of horses instead of men; that when it is raised to a proper height, it readily disengages itself, and falls with the utmost freedom; that the forceps or tongs are lowered down speedily, and instantly of themselves again lay hold of the ram, and lift it up; on which account this machine will drive the greatest number of piles in the least time, and with the fewest labourers.

The piles at Westminster bridge, when driven by the above machine till they were quite firm, were cut off, under water, by a machine, to be level with the surface of the ground to found the piers upon. This machine consisted of a framing which was adapted to fit upon the upper part of the pile, and could be fixed fast thereto. The lower part of this frame formed guides for the saw, which reciprocated horizontally at a certain depth beneath the top of the pile, and had weights to cause it to advance up to the cut. The saw was put in motion by ropes from each end, which were conducted, over proper pulleys, to two men standing on a float or raft at the surface. After fixing the machine, before the sawing was begun, the whole machine was suspended by a tackle, which therefore took up the top part of the pile with the machine as soon as it was cut off. This was the invention of Mr. Etheridge, carpenter to the works at Westminster bridge; it was very effective, as the time employed in cutting off a fir pile of 14 or 16 inches square, in ten feet depth of water, was seldom more, and often less, than a minute and a half. A machine, more convenient than this in its application, and not less effective, has been since invented by Mr. Foulds, to whom the Society of Arts presented a gold medal for the invention; see *figs. 5* and *7*. A A B is the external frame, consisting of four parallel rails A, framed into two others, B, at right angles, with proper cross pieces to unite them, and inclined to strengthen the whole; within this frame a second, or internal frame, D E, is situated; like the other, it has four parallel pieces, D and E, connected together into one frame by cross pieces; at the top it has two pieces *a, a*, which rest upon the beam B, and suspend its weight, and on these it is capable of sliding backwards and forwards between B B, always preserving its parallelism, because it is moved by the racks, *d, d*, affixed to it, one at top, and the other at the bottom; the pinions for both are fixed on a vertical axis *e*, supported in the external frame; therefore, by turning the handle *r*, the internal frame with the saw is advanced to the pile, as at K, *fig. 6*. The saw itself is sustained in a frame L, *fig. 7*, which fits, in the manner of a sash frame, between the two beams, D, of the internal frame, and has racks, *f, f*, (dotted) behind it, which work in pinions on an axis *g*, extended across the frame, and by the handle, *y*, of this it is capable of being drawn up and let down, or detained at any height by a ratchet-wheel and click *x*; the saw, *m*, is fixed upon a spindle N, supported in bearings on the frame L, and turned by the handle, R, at the top; the saw is connected with the spindle by a piece of iron *p*, having a mortise through it for the reception of the spindle, to which it is fastened by a nut beneath: by this means the saw's edge may be advanced as the work goes on.

In using this machine, the beams, B, are fixed across a barge, which is ballasted till they are horizontal, and the spindle of the saw is therefore vertical in this state; it is moored with her side against the pile, K, to be cut off, as

shewn by the dotted line V, *fig. 6*; then by the rack and pinion *f g*, the saw is adjusted in height to the level where the pile is to be cut; by the handle *r* it is advanced to the pile K, whilst by the other handle, R, the saw is kept in continual motion backwards and forwards, till the pile is cut through, and the piece is taken into the barge, which proceeds to cut off the next by the same means. By this machine temporary piles, which are used in coffer-dams, may be cut off level with the bottom, when the work is finished, which is a very superior method to drawing them up out of the ground, as is the usual practice, because this must necessarily make a deep ditch or trench all round the pier or foundation, and tend to loosen the ground. To draw piles out of the ground when they have been driven fast, requires a very great force. There are different methods of exerting this force: one for drawing them in water, is by having a very strong barge, with a windlass at one end to receive a strong chain, which is passed several times round the head of the pile, and made fast to the barge; two long beams are laid upon the barge to form a railway for a small waggon to run upon from one end of the barge to the other, and it is loaded with stones of several tons weight; when this is wheeled to one end of the barge, it will of course depress it in the water, elevating the other; then, in this state, the lowest end of the barge is chained to the pile by putting a very large bolt through it, and passing a chain round the pile under this bolt a great many times; the carriage is then wheeled to the other end of the barge by a windlass and rope; this tends to raise the end to which the pile is fixed; and when the carriage is so far advanced that it exerts a sufficient power, it will draw up the pile if the chain is properly fixed: the carriage is now returned to draw another pile.

A plan has been adopted at the new bridge now building across the Thames at the Strand, for drawing the useless piles by one of Mr. Bramah's hydrostatic cylinders. This is represented in *fig. 10*, where A is supposed to be the top of a range of piles forming the coffer-dam, and B the pile which is to be drawn. A chain, *a*, is made fast to the pile, and carried many times round a large beam C D, the end, D, of which rests upon a fulcrum, or support E, consisting of a block, supported on the head of a neighbouring pile, &c. F is a block of wood, screwed together in two places, and inclosing between them a cast iron cylinder *b*, into which is fitted the piston, or cylinder *d*, the joining being made tight by a collar of leather; *e* is a small copper pipe, communicating with the cylinder, and also with a small forcing pump, the piston, *f*, of which, is actuated by the lever *g b*; the pump is fixed upon the top of a small cistern, *k*, to contain water. Now by working the lever of the pump, water is injected into the cylinder *b*, and protrudes the piston, *d*, from it with a force proportioned to the force exerted upon the lever, in the same degree as the areas of the pump to that of the cylinder multiplied by the proportions of the lever *b*. (See this principle more fully illustrated under MACHINERY, and PRESS, *Hydrostatic*.) By this means the power of one or two men is increased to such a degree, as to draw up the largest pile; the copper pipe, *e*, is made to unscrew at

several joints, which are provided with leather, to make them tight; by this means the pump is separated when the machine is to be removed. As it has no connection with the beam or lever D, the cylinder is frequently employed in the manner of a hand jack, for any purposes where enormous weights are to be lifted for a small space; the collars of leather are the same as are used in the presses. The same figure also shews a very complete way of catching fast hold of the pile, instead of putting a bolt through the pile head to stop the chain under: it is simply a strong iron ring, *l*, large enough to drop over the pile loosely, and having a strong shank or eye, *m*, projecting from it to run the chain through; and when this is drawn, the ring jams so forcibly upon the wood of the pile, as to draw it out of the ground rather than slip off, for it holds faster in proportion to the force.

The theory of Mr. Valoue's engine depends on the following principles, *viz.* 1. If the resistance of the ground, and the masses of the piles be equal, the depths to which they will be driven with a single blow will be as the product of the weight of the ram into the height through which it falls.

2. If the masses of the ram, and heights through which it falls are both equal, the depths to which the piles will be driven, will be in the inverse ratios of the masses of the piles into the superficies of that part of them which is already immersed in the earth.

3. If all these things be unequal, the depths will be in a ratio compounded of the direct ratio of the heights through which the ram falls into its mass, and the inverse ratio of the mass of the pile into its immersed superficies.

4. If the weights of the ram be equal, and also the weights of the piles, the depths to which they will be driven will be as the heights through which the ram falls directly, and the immersed superficies of the piles. Or, because the immersed superficies of the piles are as the depths through which they are already driven into the earth, these depths are simply as the square roots of the heights through which the ram falls.

These principles are founded on the general supposition that the space through which the weight falls is estimated by the product of its mass into the square of its velocity, or into the height through which it falls.

Hence it is inferred, that the distance through which a pile will be driven by each succeeding blow will be less and less, as the superficies of that part of the pile which is immersed in the ground increases; and, consequently, that there is a certain depth, beyond which a pile of a given mass and scantling cannot be driven; the mass of the ram and the height through which it falls at first being assigned. It appears also, that the loading the pile with weights, and thereby increasing its mass, will be so far from accelerating its descent, that it will absolutely retard it. See some curious observations on the structure and operation of this engine by Mr. Bugge, professor of astronomy and mathematics in the academy of Copenhagen, &c. in the Phil. Trans. for 1779, vol. lxi. part i. art. 12.

PILE is also used, among Architects, for a mass or body of building.

Pin

PIN, in *Commerce*, a little necessary implement, chiefly used by the women in adjusting their drefs.

The form and application of this little article need no description; but its consumption, and the number of hands it employs, are too considerable to be passed by unnoticed.

Pins are now mostly made of brass-wire: formerly they likewise made them of iron-wire, which, being blanchèd, like the others, passed for brass; but the ill effect of those pins has almost altogether discarded their use. The French, however, could not be driven off from them without several arrears of parliament. By a sentence of the lieutenant de police, July 1695, the seizure of some millions of those pins was confirmed, and the pins condemned to be burnt by the common executioner.

The pins most esteemed in commerce are those of England. The method of manufacturing this useful article, that has been long practised, is as follows. The brass wire, of which these implements are now almost wholly made, is

generally too thick for being cut into pins. It is, therefore, reduced in size, by causing it to pass through a small hole in a piece of iron. When it has been reduced to a proper size, it is straightened, and subsequently cut into proper lengths; and again afterwards cut into smaller ones, each length being sufficient for making several pins. Each end of these pieces is pointed, so as to be sharp enough for penetrating, without difficulty, through linen, paper, &c. by either men or boys, seated before two small grinding-stones, or steel-mills, that are turned by a wheel, either by means of machinery or of the hand. These stones, or steel-mills, are used for making the rough point, and for smoothing them; and, therefore, they are careful to turn the wire, so as to render the points uniform and regular. The pin is afterwards cut off to the length that is wanted, from each end; and the process is repeated; till the whole of the length is pointed. The manufacture of the head is performed by the following operations. A piece of wire, suitable for heads, is spun on another; and thus the inside wire occasioning the

upper wire to be hollow, when drawn off, is then in the state required for being cut into heads: this is done by shears, every two rounds of the wire making a single head. The next process is that of heading the lengths, which is done by the operators or work-people taking up a single length, and thrusting it among the heads, and then immediately placing it under a heavy weight or hammer; when receiving the necessary blow, it is made secure; and thus the pin is completed in the first state. After this it is to be blanching or whitened, which is accomplished by putting the pin in a copper, containing tin and the lees of wine. When this is completed, the pin is in a state for sale, at the option of the buyer, either in a loose state, or stuck in paper for the convenience of the consumer.

Some successful attempts have been lately made by the well-known manufacturers, Messrs. Durnford, Francis, and Co., of Gracechurch-street, London, for putting on the heads of this very useful little article, with greater expedition and uniformity than had been previously done by others. We are not at liberty to disclose the process, which is ingenious, practicable, and expeditious; but to every effort for the improvement of this, and of every other article of British manufacture, we cannot but wish success.

The perfection of pins consists of the stiffness of the wire, and its blanching; in the heads being well turned, and the points filed.

The London pointing and blanching are in most repute; because our pin-makers in pointing use two steel-mills, (which are also occasionally used in the country,) the first of which forms the point, and the latter takes off all irregularities, and renders it smooth, and as it were polished; and, in blanching, use block tin, granulated: whereas in other parts they use a mixture of tin, lead, and quicksilver; which not only blanches worse than the former, but is also dangerous, on account of the ill quality of that mixture, which renders a puncture with a pin thus blanching very difficult to be cured.

The consumption of pins, and the number of artificers employed in the manufacture of them, are incredible. In Paris alone, there were anciently above one thousand people employed in it; and after the decline of this manufacture in the city, there have been annually sold above fifty thousand crowns worth of the pin-wire to the pin-makers of the neighbouring places, all brought thither from Stockholm. In the little town of Rugle, in Normandy, there were computed at least five hundred workmen employed in the pin manufacture; the whole town being peopled with them. Several thousand persons are employed in this manufacture, in various parts of our own country. Establishments of this kind are to be found in the Metropolis, Warwickshire, Gloucestershire, Essex, &c.

Notwithstanding that there is scarcely any commodity cheaper than pins, there is not any one that passes through more hands before they come to be sold. They reckon twenty workmen successively employed in each pin, between

the drawing of the brass-wire, and the sticking of the pin in the paper.

Pins are distinguished by numbers; the smaller called from N^o 3, 4, 5; thence to the 14th; whence they are only accounted by two to two, viz. N^o 16, 18, and 20, which is the largest size.

Besides the white pins, there are also black ones made for mourning, from N^o 4, to N^o 10. These are usually of iron-wire.

Lastly, there are pins with double heads, of several numbers; used by the ladies to fix the buckles of their hair for the night, without danger of being disturbed by their pricking, &c.

The manufacture of both brass and iron pins is thought by some persons to be in a degree injurious to the pointer; as it is imagined he imbibes, in the course of some years, a quantity of the dust which flies off the wire, and which, in that case, must be pernicious. He is also liable, from the constant pressure of his thumb on the stones, to a weakness in it, which not unfrequently renders him incapable of continuing the operation of pointing.

We are sorry to learn that the pin manufacture is less prosperous than it was some years ago. This decline is partly owing to the diminished consumption of this article by our fair country-women, and of course partly to the excess of the quantity made above the regular demand; which has occasioned to the master-manufacturer not only an inconvenience, but a disproportionate return of profit for the capital which it employs. Upon the whole, it is thought, that this useful class of persons is decreasing in number; and that there are no very encouraging expectations of the manufacture's soon reviving and flourishing.

The first mention of pins that occurs in the English statute-book, is found in the statute of Richard III. in 1483, prohibiting foreign manufactures; and it appears from the manner in which pins are described in a statute of the 34th and 35th of Henry VIII. cap. 6, A.D. 1543, and the labour and time which the manufacture of them would require, that they were a new invention in this country, and probably but lately brought from France. However, in about three years time, they fell into the present ingenious and expeditious manner of making them.

One of the articles of the statutes of the ancient pin-makers of Paris was, that no master should open more than one shop for the sale of his wares, except on new-year's day, and the eve thereof: this we mention in an age of luxury and profusion, to recollect the agreeable simplicity of our forefathers, who contented themselves with giving pins for new-year's gifts.

Hence the custom of still giving the name *pins*, or *pin-money*, to certain presents, which accompany the most considerable bargains; in which it is usual to give something towards the pins of the wife, or children, of the person with whom the bargain is struck.

Pipe

PIPE, a close channel for the conveyance of water, or other fluids, is of such extensive use in building, &c. as to render the consideration of its materials, and best means of forming its joints, a matter of importance to architects and engineers, that they may give stability and durability to their work, at the least expence. Water-pipes are made of wood, iron, lead, copper, stone, or pottery; and each of these materials, in different situations, has its preference.

Wooden-pipes may be procured in all countries at a small expence, are easily made, and joined together; but the great objection is their want of strength to resist a strong pressure without breaking, and their liability to decay. For water-works they are usually made of elm, or alder; oak, though far preferable, being too expensive. They are best made from small trees of the proper size; and then the bark, being left on, is thought to preserve them. The passage is bored out by a long auger, turned round by one or two men; whilst the tree is supported in a convenient position on tressels, and bound fast down upon them by ropes, to which weights are attached.

In towns where water-works are established, the demand for pipes is such as to render this method too expensive;

and machines are used to bore them, turned by horses, water, or steam-engines. The pipe-boring machine is extremely simple. A pit is first dug, similar to a saw-pit; on each side of this a long timber is fixed, and the two being united, at various points, by cross framing, forms the bed, on which the sledge slides backwards and forwards as great a distance as the length of the tree which is to be bored. The sledge is a frame of wood, upon which the tree is laid when it is to be bored, and is firmly held upon it by chains passed over it, and drawn exceedingly tight with windlasses fixed in the sledge. Wedges of wood are used to support it from rolling sideways, and to raise it up to such a height, that the borer will pass through the centre of the tree. The borer is fixed at the extremity of a spindle, supported by bearings, on blocks raised from the cross framing of the bed at one end, and which are adjusted, that the line of the borer will be exactly parallel to the bed and sledge: the spindle is put in motion by wheel-work from the mill, so as to revolve 30 or 40 times *per* minute. The sledge with the tree is advanced towards the borer by ropes, which are conducted over proper pulleys, from each end of the sledge, to the barrel of a wheel, with handles on its circumference, similar to the steering-wheel of a ship: therefore, a man, by

turning the wheel one way, advances the slider, with the tree towards the borer, which penetrates into the end of it; but on turning the wheel in an opposite direction, it is withdrawn, to clear the chips of wood. This is repeated till the pipe is bored through. The borer can be detached from the spindle, to employ another of greater or lesser diameter, when the pipes require it. The elm pipes employed in the streets of London for the distribution of water, are made by this means, except such trees as are crooked: these are bored by hand augers, because they must be pierced from both ends to meet in the middle, which the machine will not readily do.

The lengths of pipe are joined together, by enlarging the bore at one end in a conical form, with a fort of auger, and cutting the opposite end taper, to drive into the conical end of the adjacent pipe, which is hooped to prevent it from splitting. This method is a very bad one, very soon decaying, even when the taper end is fitted perfectly, because the thickness of the wood at the taper part is so very small. In the usual mode of fitting them, by merely shaping the conical part with the axe and drawing-knife, whilst the workmen are perhaps over shoes in mud, and exposed to bad weather, it is scarcely reasonable to expect them to be very attentive; but the joint is fitted in haste, and dispatched as quick as possible: the consequence is, that the conical part being correctly bored, whilst the taper is made to an irregular and more obtuse cone, the joint fits only at a very narrow point; but if well driven, will make a tight fitting at first, and, when buried, escapes detection; but in the course of a very few years, the vacant space round the end of the taper accumulates mud, which hastens the decay of the wood, and the joint fails. From these circumstances, the pavement of the streets is constantly broken up, the way impeded, and the supply of water suspended. The Society of Arts have, under these considerations, offered a handsome premium, for several years past, to procure a complete remedy for these defects. Mr. Hornblower proposed a tool, or bit, to form the taper end of the pipe, with the same certainty as the cone which is bored. It consisted of a wooden plug, fitted to the bore of the pipe, and having through its centre a hole, for the reception of a round iron rod or axis, which has a cross handle at the end, like an auger, to turn it round by. Near the handle, its size is sufficiently enlarged to have a mortise, for the admission of an iron arm, which can be fixed in it by a wedge. This arm turns down, and carries a steel knife, the edge of which, by the bending, is inclined to the round rod, in the angle the conical taper is to have: therefore, by turning the handle round, the edge of the knife describes the surface of the cone, and cuts away the wood of the pipe to that form; the round rod, being of considerable length, can slide freely in the plug at the end of the pipe, and allow the cutter to be thrust up, to cut by degrees, till it reduces the taper. The use of this tool would ensure the perfect fitting of the joints; but still the plan is defective, as before mentioned, from the small quantity of wood round the joint. Another kind of joints have, therefore, been proposed: in these the adjacent ends of the pipes to be joined are both bored out, by a taper bit, to hollow cones; and the two are united by a short iron tube, which is made in form of two truncated cones joined at their bases, and of dimensions correspondent with the conical bases in the ends of the pipes. This plan is very far preferable to the former, both in strength and durability; and as the tubes are made of cast-iron, it is not an expensive one.

Messrs. Eckhardt and Lyon obtained a patent in 1806, for a method of making wooden pipes by separate staves,

resembling a barrel, but of less curvature, and greater proportional length, so as to approach near to a cylindrical form, particularly withinside. They are to be bound by iron hoops, made fast either by driving them on from the ends, or by screwing the hoops together: the lengths are to be joined together, by forming one end of each taper, and enlarging the corresponding ends of others to receive them: the staves are to be fitted by tongues, rabbeting, or dovetailing. We have not heard of this method having been practised to any extent: it would, we think, be very expensive, and have all the defects of wood pipes; being liable to speedy decay, when buried in the ground. And it generally happens, that in their rotten or decayed parts they generate insects and animalculi in vast numbers; which may always be discovered in water that has passed through wood pipes or pumps, which have been long in use. Dr. Buchan observes, that such water becomes putrid by the corruption of the animal and vegetable bodies with which it abounds.

Iron-pipes are cast at the iron-foundries of any dimensions; and for durability and strength combined, are greatly superior to any other material: they may be procured in lengths of ten feet, and united by nuts and screws passed through flaunches, call on the ends of them. Most of the great Companies for supplying London with water have, within these few years past, adopted cast-iron pipes for their mains, and are daily increasing them, under the conviction that their permanency will compensate for the first expence. They are usually cast in lengths of ten feet, one end with an enlarged socket of sufficient size to receive the end of the next pipe. As these joints cannot be driven close, to fit like wooden joints, they require some cement. To apply this, they first caulk it, by driving a small quantity of hemp down to the bottom of the joint with a blunt chisel, and then fill the remainder of the socket with iron cement; which is a composition of borings or turnings of cast-iron, mixed up with sulphur and sal ammoniac. This is moistened with water, and rammed into the cavity; and the rapid oxydation of the iron borings unites them into one mass, and at the same time expands the bulk of the cement, so as to fill up all the space very closely. The hemp, first driven into the joint, is only to prevent the cement getting into the pipe, and to keep the water from it till it is set firmly; after which, the joint is as solid as any other part of the pipe. Another method, much used for large pipes, is to have two ears projecting from each pipe at the joint, through which screw-bolts are passed, to draw them close together. The joints are sometimes filled with lead run in, whilst melted; and others have used the Roman cement to bed the joints in.

Within these few years immense quantities of iron pipes have been laid in all parts of London, for the conveyance of water, which no sooner became generally known, than great prejudices were excited against them, under the idea that they would give the water a metallic taste, which would be injurious to the health of the inhabitants. This is clearly an error, as any one may ascertain, by examining an old cistern, or vessel of cast iron, which has only had fresh Thames water in it; and they will find it coated with a sort of japan, or smooth surface of a black colour, which is a very thin oxyd, and does not penetrate any depth: though if the water is of such a quality as to produce red rust, the iron is corroded very fast, but is still a very harmless mixture. Water having any lime in it, deposits a thin coat or incrustation withinside iron pipes, and thus completely defends them from corrosion; nor is there any danger, as some have supposed, of this incrustation increasing

to as to stop the pipes in course of time, because the water only deposits the stony matter from the attraction of the iron, which being once covered with a slight thickness, the water has no longer access to the iron. We have heard of an expedient of putting lime into the water, when it was found that the water was so corrosive as to become tinged by running through iron pipes newly laid down. A rapid current of this lime-water being caused through the whole length for a few days, the pipes became coated with the calcareous matter. At first, after this, the fresh water tasted of lime, but it became pure in a short time, because, in the first instance, more lime was deposited than could be combined with the oxydated surface of the iron, and this excess would of course be carried away again by the fresh water, but no more.

Stone Pipes.—The prejudice the public at first entertained against iron pipes, induced many projectors to find out other substances, which would have the strength and durability of metal. Sir George Wright proposed stone, and invented a machine for cutting out cones from the hollow of the pipe. He first employs a boring or drilling machine, to pierce a small hole through the centre of the block of stone, in the axis of the intended pipe. Another machine is then used, consisting of a saw applied in a frame, which revolves on a round iron rod, passed through the central hole previously drilled: the frame gives the means of fixing the saw at any required distance from the rod, and attaching it firmly thereto at each end: its edge will of course, when turned round, describe the surface of a cylinder, of the diameter of the intended pipe. The saw and central rod are rather longer than the block of stone, which permits them to be moved backwards and forwards endways, to give the motion of sawing with sand and water in the usual manner. In their operation, the block of stone is placed with the rod horizontal; the saw is entered at another hole, previously drilled through the stone, and as the saw cuts, the central rod guides it round on a centre, till it separates the core all round, and this being taken out, leaves a pipe or tube. Sir George obtained a patent for this invention in 1805, and it was practised for some time, and many large stone pipes were laid; but great difficulties arose in making good joints: they were attempted by Roman cement, which adhered so well, as to make them perfect, if the pipes were well bedded; but the continual tremor of heavy carriages passing over them soon disturbed many joints, and broke the bond of the cement. Mr. Samuel Hill took out a patent in 1810, for uniting these pipes together at every joint by a collar of stone, into which the extremities of two pipes are made to fit, so that about two inches of each shall enter it, and reach to its centre, where they are to meet. A sufficient quantity of cement is to be spread on the ends of each pipe, and in the internal part of the collar, before they are inserted into it, to prevent water from passing through the joints. Although this obviates one difficulty, still the expence of stone pipes is prodigious; at least in London, where the price of materials alone, without any cost of workmanship, would be too great. In situations where that material is plentiful, they may be used, and the labour of making them will be reduced very low by a machine invented by Mr. Murdoch, and for which he had a patent in 1810: it is very superior to the above, which is only applicable to large pipes; besides, the trouble of previously drilling two small holes the whole length of the pipe is wholly saved.

When it is intended to form a pipe or hollow cylinder of stone by Mr. Murdoch's machine, instead of reducing the whole inside to powder, it is sawed in the form of a core, or solid cylinder, the diameter of which is about half an

inch less than the diameter of the inside bore of the pipe. In like manner, when a solid column or cylinder is to be formed, the outside and superfluous parts of the stone are taken away by a similar process, and the core forms the column or cylinder required. When the stones are large enough to leave the outside parts of a proper thickness, they may be used as pipes; or the cores cut out of large pipes may be used as columns, or formed into smaller pipes, so that in some cases several may be cut out one within another. The method by which these are formed is the following:

The block of stone, out of which the pipe is to be formed, is placed in a vertical position, and a plug of wood or metal is fixed in the top of the block, at the centre of the intended pipe; this plug has a hole in its centre, for receiving the lower pivot of a vertical spindle or axis, which is made longer than the pipe is required to be. The rod is of an uniform thickness, and made either square, triangular, or any other shape that will admit of sockets sliding freely up and down, without turning round upon it. On the upper part of this spindle a socket is fitted, having on the middle part of its outside a pulley or a small-toothed wheel, by which the axis or spindle may be turned round. The upper and lower extremities of this socket are cylindrical, and serve as gudgeons, upon which it turns in a frame, and steadies the axis. Near the lower end of the vertical axis a wheel with arms is fixed, having the circumference like a hoop two or three inches broad; and its diameter a little less than the diameter of the pipe to be bored: it fits to the inside of a tube of metal, which is attached to the spindle, and kept concentric with it, by being fitted over the wheel. The upper part of the spindle is perforated to a little below where the above-mentioned socket is fixed, and then the perforation comes out obliquely. The tube is of a diameter nearly equal to that of the pipe to be formed, and exceeding it in length about two feet: this pipe is made as truly cylindrical as possible, and is attached to the axis by another wheel across, similar to that at the bottom, which is fixed in the tube at the upper end, and fits upon the square spindle, to slide freely up and down, without turning round upon it; this tube being, as before-mentioned, guided by fitting on the wheel fixed at the lower part of the spindle. On the lower edge of the tube a rim of proper metal is fixed, which is so much thicker than the tube, that the groove it makes in the stone may admit the tube to move freely. This hoop being intended to grind or saw the stone, has its lower edge either left smooth, or formed like the saws used by stone-cutters. The wheel or cross, which is fixed on the vertical tube, near its upper end, has a small cord or chain fastened to one of its arms, and passes upwards through the perforation in the upper part of the axis, and then over a pulley fixed at a convenient distance above it: it serves to raise the tube on its axis when required. On the upper part of the tube weights are fixed, for the purpose of making it act more forcibly upon the stone, if necessary. When the apparatus is to be put in motion by the force of man, the above-mentioned pulley, fixed in the socket near the upper part of the axis, is generally made about double the diameter of the pipe to be bored, and a rope passes round it, each end of which is conducted over a vertical pulley, fixed at a convenient distance, on each side of the machine; by which means the ends of the rope turn downwards, and having handles fixed to them, are pulled alternately by a man at each end, so as to cause the tube to make a reciprocating rotative motion about its axis or spindle: or the apparatus may be put in motion by any other power, only if the pulley and cord be retained, a spring or a sufficient weight acts

at one end, while the power operates on the other by means of a crank, or other similar contrivance. Or, instead of the pulley, a toothed wheel or pinion is substituted, and acted upon by a reciprocating toothed wheel, belonging to the mill, engine, &c. connected with the moving power, or by a reciprocating rack or sector, put in motion by the same power or machinery. A cistern is placed at some convenient height above the tube, by means of which, a mixture of water and sand is conveyed into the tube, and forces its way under the saw, when in motion, and causes it to abrade or grind away the stone, and form in it a circular groove, concentric with the axis. As the groove becomes deeper, the water accumulates in the tube, and forces the sand with it under the saw and both are discharged over the outer edge of the tube, in the form of mud or sludge, and the motion of the tube may be thus continued as long as the moving power is maintained. When any circumstance causes this to stop, the tube must be drawn up by means of the cord and pulley for that purpose, or the sand will set fast round the tube, and will not be easily freed again.

Copper-pipes are too expensive to be employed except in particular situations. They are made of copper plate turned up and folded, and are much used in distillers' work, because they can be tinned withinside, and then communicate no taint to what passes through them.

Lead-pipes are universally employed for all small water pipes, chiefly from the facility of bending them in any direction and folding their joints. Although some kinds of water corrode the metal by degrees, this will not produce so much harm as iron under the same circumstances, but would be a most dangerous poison if it was used in sufficient quantities to have any effect at all.

The greatest proportion of the leaden pipes used in water-works, was, till of late years, made of sheet lead wrapped round an iron or wooden core, and the joint folded up. The expence and trouble of this method was considerable, and the pipes thus made extremely liable to burst at the joint, particularly if bent with a sudden angle. These defects suggested the idea of casting the lead in the form of pipes, by which means the trouble of previously casting and laminating the lead into sheets would be spared, and also the uncertainty of the folded joints. Such pipes are cast in an iron mould, made in two halves, forming, when put together, a hollow cylinder, of the size of the intended pipe. A core, or iron rod, the size of the bore of the pipe, is adapted to this hollow mould when the halves are put together, and secured by screws or wedges, so that it exactly occupies the centre of the hollow mould, leaving therefore an equal space all round between them. A spout, or entry for the admission of the melted lead, is made by a corresponding notch cut in each half of the mould, and at another place is a similar vent for the escape of the air. This mould is fixed down upon a long bench; and a rack, moved by toothed wheels and pinions, is fitted up at one end of it, in a line with the centre of the mould. A hook at the end of the rack, being put into an eye at the end of the core of the mould, affords the means of drawing out the core, when the pipe is cast round it by pouring the melted lead into the mould, with the core in it: when the lead is cold, the core is drawn out very nearly to the end of the pipe, by the rack and wheel-work before mentioned. The halves of the mould are then separated, and the pipe moved along in the mould, so that only an inch or two of its end remains in the mould, the halves of which are again fastened together with the core between them, and its end entered an inch or two into the first piece of pipe. The mould is now filled with melted lead, the heat of which fuses and unites it with the end of the first piece, so as to double

its length. The core is again drawn out a second time, and another length cast to the former. This method produces pipes of any length in one piece, but they are liable to have air-bubbles in them, which produce holes when the metal is thin, and the joinings of the different lengths are not always perfectly sound.

The method which is now very generally adopted, is to cast the lead in an iron mould, upon a cylindrical iron rod of the size for the bore of the intended pipe, the lead being three or four times the thickness of the intended pipe, and in short lengths, which are then drawn through holes in pieces of steel, in the manner of wire drawing, till the pipe is reduced to the intended thickness, and drawn out to the proper length. Another method is to reduce the pipe by repeatedly passing it through the two rollers of a flattening mill, in each of which a number of semi-circular notches are formed all round, so that the two rollers, when put together, have a number of circular cavities between them, which gradually diminish in diameter from one end of the rollers to the other. Drawings of such rollers will be found in our plates of *Iron Manufacture*. The pipe is first rolled between the largest of these cavities, then in a smaller, and so on to the last, which extends the pipe to its proper length, and diminishes its substance to the proper thickness, at the same time by condensing the metal hardens it, and makes a very strong tube with very little metal. Mr. John Wilkinson of Broseley, the celebrated iron manufacturer, took out a patent, in 1790, for the last mentioned method, which he practised on a very extensive scale: he was not, however, the original inventor, the same thing having been proposed, in 1728, by M. Fayolle; see "*Machines Approuvées par l'Académie Royale*," vol. v. p. 50. Since the expiration of this patent many manufactories of this article have been established, some employing rollers, and others the draw-bench, for extending the pipes.

We have given a representation of one of the latter machines in *Plate XL. Mechanics*. *Figs. 1 and 2* are sections of the mould for casting the pipes; *A A* is the bench, supported on legs like a stool in an inclined position; *B, B*, are the two halves of the mould, fitted into each other with double rebates, as shewn in the section *fig. 1*, that they may come together correctly, and are held so by the screws *D, D*, fitted through pieces of iron *E, E*, fastened to the bench; the halves of the moulds have at each end a flat side beneath, which rests upon the iron plate connecting the two pieces *E, E*; *F* is the core, held in its position by collars at each end of the mould embracing it; *G* is the rack, and *H I K* the wheel-work for drawing out the core; *d* is the entry for the metal, raised up to the same level as the highest point the metal is intended to run into. The intention of the inclined position for the mould is, that the metal may run in at the lowest point of the mould, and expel the air as it rises, at a vent in the highest point of the mould, which is *e*. By this means the danger of air-bubbles in the pipe is avoided. The interior surface of the mould is bored out truly cylindrical, and the core being turned in the lathe, they are certain when put together to leave an equal space all round, a circumstance which is essential to form a good pipe, as the succeeding process of drawing will tend to make an error of this kind worse. The core, *F*, is seen in *fig. 2* to have a neck or smaller part at the end *d*: the treble or core *ag*, *fig. 3*, upon which the pipe is to be drawn, is of the same size, and has a similar neck, so that the pipe, when put upon it, fits it in every part, as is shewn in *fig. 3*, and the shoulder of the neck prevents the treble being drawn through the pipe in the direction from *g* to *a*, as it was put in by the opposite direction. Beyond the neck the treble has a notch cut in each side at *g*, leaving

a neck; and by this it is seized in a sort of claw belonging to the draw-bench, which is exhibited in *figs. 4 and 5*, the former being a plan, and the latter a section. In these *L, M*, are two strong timbers, bolted to uprights *N, O*, at one end of each, and to a cross beam, *W*, at the other end; the uprights support bearings for the gudgeons of a strong iron spindle, which has the cog-wheel, *k*, fixed upon its end, and is turned round by the pinion *l*, receiving a rotative motion from a steam-engine or water-wheel; *P* is a roller, fitted on the spindle so as to slip round freely upon it; it has two claws affixed into it at one end, which are seized by the ends of an iron bar, *m*, fixed fast upon the spindle. By this means, when the roller is thrust towards *m*, it is engaged with its arms, and compelled to turn round with the spindle, but when drawn back from *m*, it is at liberty to slip round independent of it; *Q* is a lever affixed to a vertical axis; it is forked at the end, and embraces a collar upon the end of the roller, so as to draw it backwards or forwards, and by this means engage or disengage it from the spindle at pleasure; *R* is another lever on the same spindle, to the end whereof a long rod, *S*, is jointed, and this has several handles fixed to it, as shewn in *fig. 5*, by which it can be moved, and the machine stopped or put in motion by a man standing at any part of the long bench *L, M*; the roller, *P*, has a pair of spiral grooves formed on its circumference, for the reception of two chains, *n, n*, which wind upon it; the ends of these chains are hooked to a little carriage, *p*, running upon two wheels, and having in its hinder part a fork or double claw, to catch in the notches at the end of the treble *T*, also shewn in *fig. 3*; *X* is a cast-iron frame, securely bolted down upon the cross beam *W*; it has a notch in its upright side, which is nearest the roller, to allow the treble and pipe to pass through, but at the same time forms a lodgment for the steel plate, through which the pipe is to be drawn. The workmen are provided with a great number of these plates, one of which is shewn in *fig. 6*; they are called whistles: the sizes of the holes through them diminish very gradually, from the diameter of the rough cast pipe, to the size to which it is intended to be reduced. The holes through them are made rounding at each side, as is shewn in the section *Z*, *fig. 6*, to facilitate the exit and entry of the pipe. The bench is continued beyond the beam *W*, and has a number of rollers in it, to support the pipe as it is drawn along.

The process of drawing is as follows: the lead pipe being fitted upon the treble, as in *fig. 3*, is laid upon the rollers in the bench, and the end of the treble being put through the largest of the set of whistles, its end is hooked into the claws in the carriage *p*, and the whistle lodged against the cheeks of the frame *X*: the rod, *S*, is now pulled, which engages the roller with the spindle (supposed to be all the while in motion); this winds up the double chains *n*, drawing the pipe through the whistle, by which it diminishes its size and lengthens it out: when the pipe is drawn quite through, the roller is cast off by pushing the rod *S*; the treble is unhooked from the carriage, and pushed back upon the rollers in the bench to its former position; another smaller whistle is put on; the carriage is drawn back by hand (the roller turning round on its spindle), and the pipe is drawn through it as before. In this manner the business proceeds till the pipe is finished.

Sometimes the pipe is drawn through twelve sized whistles in this case; the second time, and also the last time but one, it is drawn through a whistle such as *Y*, *fig. 6*; it is not rounded off at the entrance, but having a sharp edge, it cuts off shavings from the surface of the lead, making it perfectly smooth and true: this makes it pass more easily through the succeeding whistles. Lead pipes are by this

PIPE

process drawn out to ten or twelve-foot lengths, three of which are united into one, by what is called *burning*. For this purpose an iron core is put through one pipe, and entered a few inches into the other: a small iron mould is now put together in two halves over the ends of the two pipes which are brought in contact, the mould exactly fitting both; melted lead is poured into the mould, and it runs out again at a hole in the bottom. This is continued till it is supposed the heat of the lead has fused the ends of both the pipes; the hole in the bottom is then stopped by a slider for the purpose, and the mould remains full: when cold it is taken off, and the pipes are perfectly united. The core is now withdrawn, to facilitate which, it only fits the bore of the pipe at a few inches of the end. These joints are very good if the pipe remains straight, but are apt to leak if a bend is made at one of them.

In 1804, Mr. Alderfer took out a patent for lead pipes which were to be lined with tin, for the conveyance of beer, water, or other fluids which were in danger of receiving a taint from the corrosion of the lead. This he accomplished by casting a lead pipe in the manner above-described, then withdrawing the core, and throwing into the pipe a small quantity of powdered rosin. Another core smaller than the former is next inserted into the centre of the pipe, and melted tin poured in to fill up the space. The pipes are cast in a vertical position, and the rosin melting by the heat floats upon the surface of the tin, and acts as a flux to unite it with the lead. This pipe of lead, lined with tin, is now to be drawn or rolled to length, as before-mentioned. We are informed Mr. Alderfer employs rollers to extend them instead of the draw-bench.

Mr. Bramah's method of making lead pipes is very ingenious; it is performed by a process of pumping or forcing the metal, in its fluid state, through proper moulds. A boiler or kettle is fitted up over a fire-grate, with flues for the fusion of the metal; in the centre of this boiler a forcing pump is fixed up, its suction valve drawing in the melted lead contained in the boiler: the forcing pipe of the pump proceeds through the side of the boiler, and conducts the lead to the mould, which is fixed on the end of the pipe outside of the boiler: it consists of a tube, bored perfectly smooth and cylindrical, its interior diameter being equal to the outside of the pipe intended to be made; the end of the mould nearest the boiler expands into a conical mouth, larger than the mould itself, and across this widest part a cross bar is fixed, to support a core or mandrel, of a diameter equal to the bore of the intended pipe, and situated exactly in the centre of the mould, leaving an equal space all round between them: the core is slightly conical, being rather less at its extremity, which terminates at the same length with the external mould. There must be sufficient openings left at the sides of the cross bar supporting the core, to allow the lead to pass freely by, that it may unite again after passing the cross and completely fill the mould. The mould passes through one of the fire flues surrounding the boiler, that it may be kept so hot as to procure the lead in its fluid state, till it arrives nearly at the point of the mould, which is immersed in a cistern of hot water. The operation is simple: the pump, being worked, forces the lead through the mould, the heat and length of which are so regulated, that the lead may chill a little before it quits the extremity of the mould, and issues forth in a solid state into the water cistern, forming a pipe of any length. Mr. Bramah took out a patent for this method in 1797.

Pipes of pottery ware are usually made of that coarse kind of brown stone pot, which is very hard and durable; they can only be made in short lengths, and have one end enlarged

PIPE

to receive others. To close the joints tow and pitch are used, but they can never be made to bear any pressure, are liable to be broken by accident, and being very expensive, have no other recommendation than preserving the purity of the water they convey.

We have seen some water conduits from an old Roman building, which were very slight pottery tubes, buried in a mass of mortar, that by ages had acquired a hardness and closeness sufficient to resist a strong pressure.

In 1808 Mr. W. Bell obtained a patent for a new kind of pipes for conveying water, which were to be made of such substances as to give no taint to the water passing through them. He proposed tubes of porcelain pottery, and various compositions which are vitrifiable, and are not liable to corrosion or decay: the tubes are formed in such a way at the ends as to fit one within the other, and are to be made water tight by cement; they are to be enclosed in cast-iron cases, to give them strength to resist the internal pressure of water, as well as to defend them from accidental violence; or the cases may be made of wood.

PIPE, Tobacco, an implement used in the smoking of tobacco, consisting of a long tube, made of a particular kind of clay baked hard: at one end a little cavity or furnace is formed, called the *bowl*, which is for the reception of the tobacco when burning, and the fumes are drawn by the mouth through the other end of the tube. The making of tobacco pipes forms a considerable trade in London and other great towns; they are made of various fashions, long, short, plain, worked, white, varnished, unvarnished, and of various colours, but the same process is followed for all of them. The clay is found in the isle of Purbeck, in Dorsetshire, and is distinguished from others by its perfect white colour, and its great adhesion to the tongue when baked, occasioned by its great affinity for water: even in the raw state it has this property in a slight degree. The clay is prepared by dissolving it in water in large pits, and the solution being well stirred, is run off into another pit, where it deposits the clay, which, when the water has become clear and run off, is taken up for use, all impurities of small stones, sand, &c. being separated from it and left in the first pit. The clay is now divided into portions, each sufficient to form one pipe, which are rolled on a table, under the hand, into long rolls, each with a bulb at the end, to form the bowl; and these are laid by a day or two, to dry sufficiently for the pressing. This is done in an iron mould, consisting of two halves, which when put together leave a cavity of the shape of a pipe; a wire is thrust up the roll of clay, to form the bore of the pipe, and in this state it is placed between the two halves of the mould, which are then put into a kind of press or vice, by the screw of which the two halves are forced together, and the figure of the pipe imprinted on the clay included between them; a lever is next brought down, which is so situated as to introduce a stopper into the bowl of the pipe whilst still in the mould, and force it down sufficiently to form the cavity thereof: the wire is thrust backwards and forwards, to prick the tube completely into the bowl; it is then wholly withdrawn, the parts of the mould separated, and the pipe taken out, the superfluous clay removed with a knife, and

they are laid up to dry a day or two, after which they are scraped and polished with a piece of hard wood, the tubes of the pipes curved as they are intended to be, and they are then carried to the furnace to bake, which is done in seven or eight hours for fifty gross of pipes. This furnace is fully described at the end of our article **FURNACE**.

The Turks use pipes of three or four feet in length, made of rushes, or of wood, bored at the end; they have a bowl or pot of baked earth to contain the tobacco, which they separate from the tube when they leave off smoking. To make the tube tight, some kinds are made of spiral wire covered with leather. This at the same time leaves them flexible, and the bowl can stand on the ground, whilst the smoker inhales its fumes through an ivory or silver mouth-piece at the end of the tube. Of this kind is the *hookah*, or *boukar*, used by the luxurious East Indians; it is a complete furnace or chafing-dish, with grate-bars, ash-pit, &c.; and has a tight cover over the top, with one of these flexible pipes attached to it. An officer of the court of a petty eastern prince is called *boukar boukar*, and is solely employed in managing this machine; which, having lighted and prepared, he presents the mouth-piece of the tube to his master after his dinner. In some instances, the bowl is kept in an adjacent closet, the pipe being conducted through a hole in the wall. Some of those which are most complete have another peculiarity; the smoke, before it goes into the tube, is made to pass under water, by bubbling up through it. This is found to give the smoke a mild and agreeable flavour, by depriving it of its acrid and pungent taste; and, indeed, it is for the same end of condensing these particles, that the tubes are made of such great length. We are not informed how the smoke is made to pass under the water, but have seen a simple experiment, which any one may try, to experience the improvement of the smoke by this process. Procure a common decanter or glass bottle, fill it half full of water, and fit a cork to it, which has two holes made through it by burning, sufficiently large to admit tightly the tube of a tobacco pipe: in one of the holes fit a pipe with a bowl, the tube end projecting so far down into the bottle, that it will be an inch below the surface of the water: into the other hole, fit a pipe without a bowl, not reaching to the water, but sufficiently curved or inclined to come conveniently to the mouth. Make all the joints tight by wax, fill the bowl of the pipe with tobacco, and light it; then by sucking air through the mouth-pipe, it will be drawn out of the bottle, and rarefy that within; the atmospheric air then presses through the burning tobacco in the bowl of the pipe, and carries the smoke down the tube through the water, and it rises in bubbles to the surface of the water in the bottle, from whence it can be inhaled through the mouth-pipe, by continuing to suck at it. The smoke is by this process cooled, and rendered very agreeable, by the separation of certain principles which are of a very unpleasant flavour: the existence of these principles will be shewn by the water in the bottle becoming yellow in a short time, and having a very disagreeable taste. This method of smoking may be useful to invalid smokers, who from cough, or inflammation of the lungs, are unable to continue a practice which, by long habit, has become quite an essential comfort to them.

Pits

PITS, *Brine*, the name given by the people of Worcester-shire and Cheshire, to the wells or pits affording the salt water, out of which they extract the salt.

These waters, though they all contain salt, yet have other things also in them, and these not in small quantity. They all contain a very large proportion of stony matter: this is common to the whole set, but particular substances beside

this are found in the particular pits. At Northwich, in Cheshire, there are four pits, the water of which stinks very strongly of sulphur, and contains so much vitriol, that it will turn black like ink, with a decoction of galls: yet this is boiled into a very fine and pure kind of salt, common at our tables under the name of basket-salt, and having no such properties.

There is a vast quantity of stony matter precipitated from these pans of brine, in the boiling of them to salt: this is partly saved in small pans set at the side of the boiler, and partly precipitates to the bottom of the pan, where it forms a crust like that at the bottom and sides of our tea-kettles, which the workmen find it necessary to remove every week; but there is no vitriol or sulphur separated. Phil. Trans. N° 150.

In the country near where these brine-pits are, the instruments used in boring often bring up fine and hard salt; so that they give proofs of there being rocks of salt in many places.

All along the river Weaver, on each side, the earth affords brine wherever it is opened; but all these are not fit for boiling, many of the pits affording a brine too weak to be worked to any advantage. The very strongest pits sometimes also become at once too weak: this is owing to the irruption of fresh springs into them, and sometimes the river itself makes its way into them, and overflows them with such a quantity of fresh water, that they are utterly spoiled. The brine-pits at Weston, near Stafford, afford a brine that stinks like rotten eggs: this turns instantly to ink with galls, and purges and vomits violently, if taken even in a small quantity. This, in boiling, deposits a white flaky sand, or stony matter, without smell or taste, and the salt is pure and fine.

The pit at Droitwich, in Worcestershire, affords no sand in the boiling, nor any the least sediment of the stony matter at the bottom of the pan, and the salt is the purest of all the others; and by the people of the country it is esteemed the most wholesome, because of its being without the sand.

This and the other pits hereabout, all have the smell of rotten eggs, especially after a little rest, as on the Monday morning after the Sunday's rest. If meat be put to pickle in the brine of these pits, instead of being preserved, it will stink in twenty-four hours, sometimes in twelve, yet they yield the best salt of any inland pits in the world.

The sulphur spaws of Yorkshire, which are very numerous in different parts of the county, all stink violently of rotten eggs; but if well drawn and worked, they would prove as inoffensive as the rest, and only so many weaker or stronger brine pits; and the smell is no other than that of the Cheshire and Staffordshire brine, when it has been left some time at rest. It is remarkable, that though the stony matter is deposited in such vast plenty by the waters of all our salt springs, it is not found in any abundance in those places where salt is made out of sea-sand, as in Lancashire, and some other places; so that it is much more than the natural quantity of spar contained in water that is thus deposited; and indeed it appears from trial, that the brine of our salt springs, in general, contains more than twenty times the quantity of spar that common water does.

This stony matter separates itself from the water before the salt does, and thus it appears in many other waters impregnated with mineral particles. The vitriolic waters all contain ochre and salt, and in all these the ochre separates itself first in the boiling, and then the vitriol; and the stony matter precipitated from common salt springs affords, on an

analysis, the salt called *nitrum calcareum*, in considerable abundance. Phil. Trans. N° 156. See SALT.

PITS, Forcing, in Gardening, such as are formed and constructed on somewhat similar principles to those in hot-houses, stoves, &c., and which are found of very great use and advantage in raising crops of culinary exotics, as cucumbers, and many other sorts;—in forcing common vegetables, as asparagus;—in raising young exotics, as pines and other plants;—or in producing grapes. For these general purposes, pits have been constructed with one single fire, which are capable of producing four different temperatures of heat at the same time. They are, consequently, able to force all kinds of common vegetables, and capable of growing vines, pines, and melons, each in their proper climate, with one fire, and little trouble or expence. See HOT-HOUSE and STOVE.

PIT-Coal. See COAL.

Vegetables have been considered as the materials for the formation of pit-coal; but M. Chaptal observes, that a few forests, being buried in the earth, are not sufficient to form the mountains of coal which exist in its bowels. He thinks some provision, greater and more proportioned to the effect, is requisite, and this he finds only in the prodigious quantity of vegetables which grows in the seas, and which is still increased by the immense mass of those that are carried down by rivers. Those vegetables carried away by the currents, are agitated, heaped together, and broken by the waves; and afterwards become covered with strata of argillaceous or calcareous earth, and are decomposed. It is easier to conceive how these masses of vegetables may form strata of coal, than that the remains of shells should form the greater part of the globe. In confirmation of this theory, Chaptal alleges, the presence of vegetables in coal mines; the impressions of shells and of fish that are found in the strata of coal, and not unfrequently shells themselves; and also the evidence afforded by the nature of the mountains which furnish coal, from which it appears that their formation is sub-marine; for they all consist either of schistus, or grit, or limestone. The secondary schistus is a kind of coal, in which the earthy principle predominates over the bituminous. As the origin of the schistus, on which the texture of the vegetable, and the impression of fish are well preserved, is sub-marine, the same must likewise be the origin of the coal distributed in strata through its thickness. The grit-stone consists of sand heaped together, carried into the sea by rivers, and thrown up against the shores by the waves. The strata of bitumen which are found in these cannot but come from the sea. Calcareous earth rarely contains strata of coal, but is merely impregnated with it; the bitumen forming a cement with the calcareous earth.

Pit-coal is usually found in strata in the earth, almost always in mountains of schistus or grit. The secondary schistus is the basis of all pit-coal, and the quality of the coal mostly depends upon the properties of this basis. When the schistus predominates, the coal is heavy, and leaves a very abundant earthy residue after its combustion. As the formation of the pyrites, as well as that of coal, arises from the decomposition of vegetable and animal substances, all pit-coal is more or less pyritous; so that we may consider pit-coal as a mixture of pyrites, schistus, and bitumen. The different qualities of coal, therefore, arise from the difference in the proportion of these principles. When the pyrites is very abundant, the coal exhibits yellow veins of the mineral, which are decomposed as soon as they come in contact with the air; and form an efflorescence of sulphat of magnesia, of iron, of alumine, &c. When pyritous coal

is set on fire, it emits an insupportable smell of sulphur; but when the combustion is insensible, inflammation is frequently produced by the decomposition of the pyrites; and it is this which occasions the inflammation of several veins of coal. When the schistus, or slaty principle, predominates in coals, they are then of a bad quality, because their earthy residue is more considerable. The best coal is that in which the bituminous principle is the most abundant, and exempt from all impurity. This coal swells up when it burns, and the fragments adhere together; it is more particularly upon this quality that the operation called defulphurating or purifying of coal depends. This operation is analogous to that in which wood is converted into charcoal. In the defulphuration, pyramids are made, which are set on fire at the centre: when the heat has strongly penetrated the mass, and the flame issues out of the sides, it is then covered with moist earth; the combustion is suffocated, the bitumen is dissipated in smoke, and there remains only a light spongy coal, which attracts the air and humidity, and exhibits the same phenomena in its combustion as the coal of wood. When it is well made, it gives neither flame nor smoke; but it produces a stronger heat than that of an equal mass of native coal.

It was long supposed that the smell of pit-coal is unwholesome; but the contrary is now proved. M. Venel has made many experiments on this subject, and is con-

vinced that neither men nor animals are incommoded by this vapour. Mr. Hoffman relates, that disorders of the lungs are unknown in the villages of Germany, where this material of combustion is only used. Coal of a good quality, it is supposed, does not emit any dangerous vapour: but when it is pyritous its smell must be hurtful. The use of coal is generally applicable to the arts in a variety of ways. In Scotland lord Dundonald has erected furnaces in which the bitumen is disengaged from coal, and the vapours are received and condensed in chambers, by means of water, and these condensed vapours afford an ample supply of tar. M. Faujas has carried into execution a similar process at Paris, by setting fire to coal, and extinguishing it at the proper time, so that the vapour may pass into chambers containing water for the purpose of condensing them. This tar is said to be superior to that of wood. (See TAR.) Pit-coal likewise affords ammoniac by distillation, which is dissolved in water, while the oil floats above. When coal is deprived by combustion of all its oil and other volatile principles, the earthy residue contains the sulphates of alumine, iron, magnesia, lime, &c. These salts are all formed when the combustion is slow; but when it is rapid, the sulphur is dissipated, and there remain only the aluminous, magnesian, calcareous, and other earths. The aluminous most commonly predominates. Chaptal's Elem. of Chemistry,

Pitch

PITCH, in the *Arts*, a resinous substance, which is the residuum of the distillation of tar. Resin differs from pitch in being the residuum of turpentine, which is obtained from the different species of pine without heat. Tar is obtained by cutting the wood into pieces, and exposing it to the heat by a furnace for the purpose. This accounts for the blackness of the latter, arising from the decomposition of the essential oil by heat. Hence the spirit of tar differs from the spirit of turpentine merely in colour, from the presence of carbonaceous matter. See **TAR** and **TURPENTINE**.

Pitch is properly a juice of the wild pine, or pitch-tree; and is conceived to be no other than the oil thereof inspissated, and turned black, farther than in the balsam. For the method of procuring it from the wood of this tree, see **PINE**. See also **TURPENTINE**.

The best is that brought from Sweden and Norway. Its goodness consists in its being of a glossy black colour, dry, and brittle.

This is less pungent and less bitter than the liquid tar, (see **TAR**), and used only in some external application, as a warm, adhesive, resinous substance. Neumann observes, that when melted with oils, resins, and fats, into ointments and plaster, the pitch is very apt to separate and precipitate. The ancients had a peculiar kind of pitch called *brutia*, which was inspissated to a higher than ordinary degree for certain uses; such as the receiving a proper quantity of bees' wax, to render it the zopiffa used in coating the bottoms of ships; which the common pitch could not do, being of too soft a consistence for this use. Pliny tells us that it was made in this manner: the wood was cleaved and formed into a pile, with proper trenches cut in the earth to receive what run from it in burning. When the pile was lighted, the first thing that flowed into these trenches was a thin fluid liquor like water. Lamp black is the foot of burned pitch: and it is likewise prepared by collecting the foot of pit-coal. See **Lamp BLACK**.

PITCH, *Burgundy*, is brought to us from Saxony, and is supposed to be a preparation of the same kind with the common resin of the shops, only less divested of the oil, made by boiling the common turpentine till it acquires a due consistence. Upon making an incision into the bark of the "*Pinus abies*," or Norway spruce fir-tree, a clear tenacious fluid issues, which concretes into a resinous substance, known by the name of "*resina abietis*." This, after being boiled in water, and strained through a linnen cloth, is called in the Pharmacopoeias "*Pix Burgundica*," or *Burgundy pitch*. But if the boiling of the native resin is con-

tinued till the water is wholly evaporated, and wine vinegar is at this time added, a substance of the name of "*Colophonium*" is formed. The greatest quantity of *Burgundy pitch* is collected in the neighbourhood of Neufchatel, whence it is brought into this country packed in casks. A fictitious sort is made in England, and found in the shops under the title of *common Burgundy pitch*. It may be distinguished by its friability, want of viscosity and unctuousity, and the odour which characterises the genuine sort. *Burgundy pitch* is of a solid consistence, yet somewhat soft, of a reddish-brown colour, and not disagreeable in smell. It is entirely confined to external use, and was formerly an ingredient in several ointments and plasters. In inveterate coughs, affections of the lungs, and other internal complaints, plasters of the resin, by acting as a topical stimulus, are frequently found of considerable service. See **PLASTER**.

PITCH, *Jews'*. (See **BITUMEN**.) *Jews' pitch*, or asphalt, is black, brilliant; ponderous, and very brittle. It emits a smell by friction; and is found floating on the water of the lake Asphaltites, or the Dead sea. The asphalt of commerce is extracted from the mine of Annemora, and more particularly in the principality of Neufchatel. M. Pallas found springs of asphalt on the banks of the Sock, in Persia. Most naturalists, says Chaptal, consider it as amber, decomposed by fire. It liquefies on the fire, swells up and affords flame, with an acrid disagreeable smoke. By distillation it affords an oil resembling petroleum. The Indians and Arabs use it instead of tar; and it is a component part of the varnish of the Chinese.

PITCH, *Mineral*. (See **BITUMEN**.) This is a modification of petroleum. It is found in France, in Auvergne, at a place called Puits de Lapege, near Allais, over an extent of several leagues. The calcareous stone is impregnated with a bitumen, which is softened by the heat of summer, when it flows from the rocks, and forms a very beautiful stalactites. It forms masses in the fields; and impedes the passage of carriages: the peasants use it to mark their sheep. This stone, when rubbed, emits a filthy smell. Some have asserted that mineral pitch was used to cement the walls of Babylon.

PITCH, *Naval*, *pix navalis*, is that drawn from old pines, ranged and burnt like charcoal. This, with a mixture of tow, or beaten cables, serves for paying over the seams of a ship's sides and decks, after they are caulked, to preserve the oakum from any wet; and likewise over all the surface of the bottom and wales: to pay the two latter it is softened with oil.

PITCH, *Naval*, is also a denomination given to that scraped

from off the sides of old vessels; and which is supposed to have acquired an astringent virtue, by means of the salt water. It serves to make plasters; though it is certain the apothecaries usually substitute the common black pitch in its stead.

PITCH, *Greek*, or *Spanish pitch*, is that boiled in water till it has lost its natural smell; upon which it becomes dry and friable.

The ancients called it *colophony*; from Colophon, a city in Greece, whence great quantities were brought. See COLOPHON, and *Burgundy Pitch*, *supra*.

PITCH, *Oil of*, *oleum picinum*, is an oil procured from pitch, by separating the aqueous matter that swims a-top of the melted pitch. This, from the great virtues formerly attributed to it, was also called *balsam of pitch*.

PITCH, *Ointment of*, is made by melting tar with an equal weight of mutton suet, and straining the mixture whilst hot: this is used sometimes as a digestive, and said to be particularly serviceable against scorbutic and other cutaneous eruptions. See TAR.

PITCH, *Pills of*, are made of tar mixed with so much powdered liquorice, or other such powdered matter as is sufficient

to render it of due consistence for being formed into pills. See TAR.

PITCH of *Castro*, in the *Materia Medica*, the name given by Boccone and some other writers to a thick kind of bitumen, found issuing out of the cracks of some rocks near the village of Castro: from whence it has its name: it is famous in the ecclesiastical state for its medicinal virtues.

PITCH, in *Building*, denotes the angle or gable end.

If the length of each rafter be three-fourths of the breadth of the building, the roof is said to be *true pitch*. This is used when the covering is of plain tiles.

If the rafters be longer, it is said to be a *high* or *sharp-pitched* roof; if shorter, which seldom happens, it is said to be a *low* or *flat-pitched* roof.

If the length of the principal rafters be equal to the breadth of the building, it is called *Gothic pitch*. This is used when the covering is of pantiles.

If to rule as a pediment, it is said to be *pediment pitch*. The perpendicular height of this pitch, is equal to $\frac{1}{3}$ ths of the breadth of the building. This pitch is used when the covering is lead.

Plane

PLANE, a tool used by artificers who work in wood, to produce straight, flat, and even surfaces upon that material. Almost all trades which fabricate articles of wood, employ planes at times; but as joiners make a greater use of these tools than any others, they are usually considered as joiners' and carpenters' tools. Planes have been, of late years, used by some artists to produce flat surfaces in metals. A plane operates to cut off a thin chip or shaving from the wood on which it is applied, by the sharp edge of a steel cutter or broad chissel, called, very improperly, the plane iron: this is fixed in a hole made through a wooden block, called the plane stock, and the edge of the iron projects a very small quantity through the lower side of the stock, called the *face* of the plane; the surface of which face is made a perfectly true plane. The iron is fixed in an inclined position in the hole through the stock, by means of a wedge driven in before it, to jamb it fast in the hole, which being wider than the thickness of the iron, leaves an aperture before the iron, called the *mouth* of the plane: this is very narrow where it opens in the lower side or face, but grows wider as it rises up through the stock; the wedge is also cut forked, to allow more room for the shavings which the plane iron cuts to pass up before it through the mouth. When a plane of this kind is applied with its face upon the surface of a piece of wood, and pressed down upon it whilst it is moved forwards, the edge of the iron penetrates the wood to the depth which it projects through the face, and removes a shaving of that thickness and the whole breadth of the edge of the iron, the shaving turning up before the iron passes through the mouth, and escaping. The inclination of the iron makes it cut easily; and if the iron is *set fine*, that is, if the edge projects but very little beyond the face, it will remove very thin shavings, and produce a flat and smooth surface: on the other hand, if it is *set rank*, that is, with a considerable projection, it will cut away very fast, producing a flat though rough surface, and quickly reducing the wood to its intended thickness: if the wood has an irregular surface, it soon reduces it to a plane, because the face, being flat, will not suffer the edge of the iron to descend into the hollow places, but removing all the eminences it passes over till they are reduced to one level.

This is a general description of several kinds of planes, which are all known by different names, from their different dimensions and purposes. Joiners use the *jack plane*, the *long plane*, *trying plane*, *shooting plane* or *jointer*, and the *smoothing plane*; all which they denominate *bench planes*, because the wood they are used upon is generally laid on the work-bench. They have also the *straight block* for straightening short edges, *rebating planes* for forming rebates; others, for the same use, are called the *moving filister*, *fast filister*, and *side-rebating plane*. The *plough* is a narrow plane, provided with apparatus to guide it, in moving straight, to plow a groove or trench at any required distance from the edge of a board or other piece of wood, and to any depth or width. The *dado grooving plane* is also for forming grooves.

There are several other tools, which, having an iron fitted

into a stock, are called planes, because they cut in the same manner, though, in strictness, they are not planes, for they do not make plane surfaces; these are *moulding planes*, with faces and cutting edges curved, to produce all the varieties of ornamental mouldings, and which are known by the names of *snipe's-bills*; *side snipe's-bills*, *beads*, *hollows* and *rounds*, *ovoles* and *ogees*. The varieties and different sizes of these form a vast number, with which every complete joiner is furnished. It is impossible to describe the terms applied to these tools without figures, as they are arbitrary, though generally known among workmen. The faces of all these planes are straight in the direction of their length, but a section across the face is the impression or reverse of the moulding they are intended to make, and the edge of the iron is curved to correspond with this curve when in its place, but will in reality be a very different figure, because it is inclined to the face of the plane at an angle of about forty-five degrees. Another distinction between these and the bench planes is, that their mouths do not open so as to discharge the shaving through the stock at the top thereof, but the wedge completely fills the hole, and the shaving passes out sideways through a hole for that purpose; in some, these apertures are on the right, and in others on the left side; in the first case the shaving is said by the workmen to be thrown on the bench, that is, upon the right side of the plane; but when the orifice of discharge is on the left, and consequently the shaving thrown upon the left, then the plane is said to throw the shaving off the bench. The *compass plane* is used by coach makers, cabinet makers, &c.; it is made with a convex face, formed to an arc of a circle in the direction of its length, and it therefore forms the concave surface of a cylinder. The *fork/staff plane* is straight in the direction of its length, but its face is made concave in its breadth, to the arc of a small cylinder; the edge of the iron is of course curved in the same manner, and it planes cylindrical surfaces. Coopers also employ long and heavy planes to form the edges of the staves of barrels; these are mounted in an inclined position on legs like a stool, with their faces upwards, and the staff is drawn backwards and forwards upon them.

Planes are so necessary for all kinds of work, that any who intend to work in wood, should understand the structure and the manner of using them. The *jack plane* is used for taking off the rough and prominent parts from the surface of the wood, and reducing it nearly to the intended thickness, in coarse shavings or slices. The stock of this plane is about seventeen inches in length, three inches high, and three and a half inches broad; all the sides are straight and at right angles to each other: the mouth is cut through the solid of the stock to receive the iron, and hold it at such an elevation, as to make an angle of forty-five degrees with the face of the plane; the iron is a thin metal plate, one side consisting of iron the other of steel; the lower end of the iron is ground to an acute angle off the iron side, forming a sloping part called the *basil* of the iron, so as to bring the steel side to a sharp edge: the wedge which fixes the iron in its place, is

let into two grooves of the same form, on the sides of the opening or mouth: two sides of the wedge are parallel, and it is forked or cut away in the middle, leaving the sides like two prongs, to fill the lower part of these grooves; this allows the shaving to pass up without obstruction before the wedge: for the mouth or opening through the stock must be uninterrupted from the face to the top, and must be no wider on the face of the plane, than is sufficient for the thickest shaving to pass with ease; and as the shaving is discharged at the upper side of the plane, the opening through it must expand or increase from the face to the top, so as to prevent the shavings from sticking therein. A handle, called the *tote*, is fixed to the upper side of the stock, immediately behind the iron; it is formed to the shape of the hand, and direction of the motion, so as to produce the most power in pushing the plane forward.

A workman in using the jack plane, lays the piece of wood on the *bench* parallel to its sides, with the farther end lodged against the *bench-book*; then laying the fore-part of the plane upon the hind end of the wood, with the right hand he takes the handle, and pressing with his left upon the fore end, thrusts the plane forward in the direction of the fibre of the wood and length of the plane, until he has extended the stroke the whole length of his arm, the shaving being discharged at the orifice; he then draws back the plane, and repeats the operation in the next adjacent rough part, proceeding in this manner until he has removed the rough parts throughout the whole breadth. He then steps forwards the distance of the length he has planed, and operates upon another length in the same manner, proceeding this way by steps, until the whole length is gone over and rough planed. To do this is very easy; but a workman will not make good progress nor do clean work, unless he has first adjusted his tool properly for the work. The methods of doing this are nearly the same for all planes. The first care is to obtain a sharp cutting edge to the iron; if it requires grinding on the grindstone, the carpenter places his two thumbs under the iron, and the fingers of both hands above, laying the basil side to the grindstone, and holding it to the angle he intends it shall make with the steel side of it, keeping it steady while the stone revolves; and pressing the iron to the stone with his fingers; in order to prevent the stone from wearing the edge of the iron into irregularities, he moves it alternately from edge to edge of the stone, with so much pressure on the different parts as will reduce it to the required bevel, and make the edge straight.

The basil being brought to a proper angle, and the edge to a regular and slight curvature, the roughness occasioned by the gritty particles of the stone are taken away by rubbing its edge on a smooth flat hone or Turkey stone, sprinkled with olive oil on its surface. As the basil is generally ground, to give a more acute angle than the edge of the iron would stand, for the quicker dispatch of wetting it, the face of the iron is inclined nearer to the perpendicular, while it is rubbed backwards and forwards with the same inclination throughout. Every time the iron becomes dull or blunt by use, the sharpening is produced by grinding on the rubber-stone, or flat grindstone, or on a Turkey stone; but in repeating this, after the edge gets thick, it requires so much time to bring it up to an edge, that recourse must be had to the grindstone. The iron being thus sharpened, must be fixed in the plane by its wedge: the projection of the cutting-edge must be just so much beyond the face of the plane, as that the workman may be able to work it freely in the act of planing, and must be regulated by the stuff to be wrought; whether it is hard or soft, cross-grained or curling; so that a man may be able to perform the most work, or reduce the sub-

stance most in a given time. If the stuff is good and clean-grained, it is evident that a considerable projection may be allowed, as a thicker shaving may be taken: the extreme ends of the edge of the iron must never enter the wood, as this not only retards the progress of working, but chocks and prevents the regular discharge of the shavings at the orifice of the plane. The projection of the cutting-edge is called *iron*, and the plane is said to have more or less iron, as the projection is greater; when there is too much iron he knocks with a hammer on the fore end of the top of the stock, and the blows will loosen the wedge, and raise the iron in a certain degree, and the head of the wedge must be knocked down to fix it again.

When he has occasion to take out the iron to sharpen it, he strikes the fore end of the top of the stock smartly with the hammer, which loosens the wedge and the iron.

All the other bench planes are adjusted in the same manner, and indeed do not differ, except in dimensions, as we shall explain, from the jack plane. Of late years, a great improvement has been introduced in the irons of planes, to cause them to cut smooth; these are called double ironed: they were at first only used in the finest shooting planes, but the advantages have been found so great, particularly in planing bad wood, that they have become general for all sorts of planes. The double iron consists of a second iron, with a reversed basil screwed against the front side of the iron, so that its edge lies against the iron at a very small distance from, and parallel to, the cutting edge; and applying closely to the steel side of the iron, it forms an inclined plane, which turns the shaving over immediately after it is separated or cut up by the edge, and thus it prevents the iron from splitting the shaving deeper down than it will afterwards cut, and therefore leaving a rough or torn surface. This second iron is called the cover of the iron; and the basil of its edge, instead of being ground flat, as that of the iron, is rounding: the screw, which binds the cover upon the iron, passes through a slit in the cover, and thus admits of its edge being adjusted at any required distance from the cutting edges of the iron, and this distance depends altogether on the nature of the wood the plane is to be worked upon. If the stuff is clean-grained, the edge of the cover may be set at a considerable distance, because the difficulty of pushing the plane forwards becomes greater, as the edge of the cover is nearer the edge of the iron, and the contrary when more remote: this is occasioned by the edge of the cover turning the shaving over immediately it is cut up.

The *trying plane* is usually twenty-two inches long, three-quarters broad on the face, and three in height; it does not differ from the jack plane, except in having a double handle, adapted for greater force: in use, it succeeds the operation of the jack plane, to straighten the wood, and remove the ridges left by the former; it is set with less iron, and cuts a finer shaving: the mouth is also much narrower. When it is used upon a long piece of work, the workman takes every shaving the whole length, by stepping forwards, instead of stopping at arm's length, as with the jack plane. The shaving of this plane, though finer, is so much broader than the jack, that it requires as much force to push it forwards.

The *long plane* is set very fine for finishing work which is to be very straight; it is twenty-six inches long, three and a half broad, and three inches in height.

The *shooting plane*, or *jointer*, is the longest, and most correct plane used; it is employed after all the others, chiefly in shooting the straight edges of boards which are to be jointed together; it is generally made two feet and a half

long, three inches and a quarter broad, and three and a half high; it is used like the others, but with great care to move it steadily from one end of the work to the other, without pressing it down, as that might spring the plane, or the work, and cause the iron to cut when the work was something hollow, whereas the object is to make a perfectly straight edge. The face of this plane must be kept quite true, and therefore it is a great object to make it of a fine piece of clean-grained, hard beech, well seasoned, that it may not warp, or vary, by the weather.

The *smoothing plane* is very short, without any handle, and its sides are curved, so that it very much resembles a coffin; it is seven inches and a half long, three broad at the mouth, and two inches and three quarters in height; it is used for finishing work when put together, and to give the greatest degree of smoothness to the wood, for which purpose it is set with as fine an edge as possible.

Rebating planes are used for cutting out rebates; these are a kind of semi-grooves upon the edge of a board, or other piece of wood, formed by cutting down or reducing a small part of the breadth of the board to half, more or less, of the general thickness: by this means, if a rebate is cut on the upper side of one board, and the lower side of another, the two may be made to overlap each other, without making them any thicker at the joint. Rebates are also used for ornamenting mouldings, and many other purposes in joiners' work. The planes for cutting them are of different kinds, some having the cutting edge at the side of the iron and of the stock, others at the bottom edge of the iron and the face of the stock, and others cutting in both these directions; the former, being used to smooth the side of the rebate, are therefore called *side-rebating planes*; whilst the others are used for smoothing the bottom. There is also a third sort, called *fillisters*, used for sinking, or cutting away the edge of the piece of wood to form the rebate, leaving it for the others to smooth the surfaces when cut. The rebate planes are about nine inches and a half long, and of various widths upon the face, from half an inch to an inch and three quarters; in all cases they have the mouth and the edge of the iron coming out at one edge of the face, and the side of the iron also exposed at one of the upright sides of the stock, whether it is formed with a cutting edge there or not: this exposed side is either on the right or left, and they are named accordingly. In all cases they throw the shaving out on the side, instead of at the top of the stock. The cutting edges and mouths are generally situated obliquely across the face, instead of being at right angles to the length of the plane, as in others.

The *moving fillister* is a rebating plane, which has a ruler of wood, called the *fence*, fixed upon its face by screws in the direction of its length, and exactly parallel to the edge of the face; it therefore covers part of the length of the cutting edge, and can be fixed at any required distance from the edge, to leave more or less of the cutting edge exposed, and this quantity will be the breadth of the rebate it will cut; because when it is used, the edge of the fence is applied against the edge of the piece to be rebated, and thus gauges the breadth its iron shall cut away. The cutting edge of this plane is not situated at right angles to the length of the stock, but has an obliquity of about forty-five degrees, the exposed side of the iron being more forwards than the other. By this obliquity, when the plane is worked, it has a tendency or drift to run farther into the breadth of the wood, but as the fence, sliding against the edge, prevents this, the drift always keeps the fence in contact with the edge, without the

attention of the workmen; it also causes the iron to cut the bottom of the rebate smoother, particularly in a transverse direction to the fibres, or where the stuff is cross-grained, than could otherwise be done, when the steel face of the iron is perpendicular to the vertical sides of the plane. The principal use is, however, to contribute, with the form of the cavity, to throw the shaving into a cylindrical form, and thereby making it issue from one side of the plane. The iron is what is called *shouldered*, that is, the lower part or shoulder where the edge is, has double the width of the upper part, which is received into the mortise, and jammed fast by the wedge. It is the edge of this wide part only which is exposed at the side of the stock. Besides this principal iron, there is another small iron, called the *tooth*, which precedes the other, to scratch or cut a deep crack at the width of the rebate, thus making the shavings which the iron cuts up from the bottom separate sideways from the rest of the wood. This tooth is inserted in a vertical mortise through the stock, between the fore end of the stock and the iron. The lower end of this little iron is ground with a bevel on the inside, so as to bring the bottom of the narrow side of the iron to a very convex edge; it is fattened by a wedge passing down before it in the mortise in the stock. The use of this tooth is principally for cutting the wood transversely when wrought across the fibres, and by this means it not only cuts the vertical side of the rebate quite smooth, but prevents the iron from ragging or tearing the stuff. The iron between the fence and the edge of the face of the plane, must project the whole breadth of the uncovered part of the face, otherwise the wood of the plane will bear it up, and prevent the plane sinking as it cuts away the rebate, and the edge of the tooth or little iron should stand out a little farther on the side of the plane than the iron. The depth of the rebate which this plane will cut, is regulated by a stop fixed on the outside of the plane, at the intended height above the level of the face: then, when the plane has penetrated or sunk the intended depth of the rebate, the stop comes to bear upon the solid of the wood beyond the rebate, and bears it off from cutting any longer. The stop is a piece of brass, which moves in a vertical groove made in the side of the stock, between the iron and the fore end of the plane; in this it is moved up and down by a screw, which is inserted in a vertical perforation from the top of the plane to the groove, and passing through a part projecting from the stop into the groove: the upper part of the screw is formed to a thumb-nut, to turn it round by, and it is so confined by proper collars, that it can neither move up nor down; but being turned, the inclination of the threads will rise or fall according to the direction in which the thumb-screw is turned, and cause the stop to move up and down in the groove on the side of the plane, thus regulating it at pleasure to the depth to which the rebate is required to be sunk.

In grinding and fixing the iron of this plane, it is necessary that the cutting edge of the iron should stand equally prominent in all parts out of the face, otherwise the plane cannot make shavings of an equal thickness; and, consequently, instead of keeping the vertical position, will, as it proceeds, become deeper on the side on which the shavings are thickest, and then the part cut away will not be regular, for the bottom of the rebate will not be parallel to the upper surface of the wood, and the side which ought to have been vertical, will be a kind of a ragged curved surface, formed by as many gradations or steps in the depth as the number of shavings.

The *jab fillister* differs in several particulars from the mov-

ing fillister: the breadth of the iron is something more than the whole breadth of the sole, so that the extremities of the cutting edge are in a small degree without the vertical sides of the stock: the fence is adapted to be moved to a considerable distance, not being fixed, as in the moving fillister, by screws upon the face, but sustained by two bars fixed fast to it, which pass through the two vertical sides of the stock, at right angles to the sides, fitting tight in the two holes through which they pass; these bars are made rounding upon the upper side and flat on the lower side: at the point where they are united to the fence, they have thicker parts, or shoulders, projecting downwards, because it is necessary to have the fence fixed on a lower level than the face of the plane: the ends of the bars are ferruled, to prevent splitting when the ends are struck with a mallet, in order to move them in the holes through the stock, and this brings the fence either nearer or more remote from the stock, as may be wanted; and to fix it fast, when so adjusted, two small tapering pieces of wood, called keys, are inserted into two small wedge-like mortises, cut at the sides of the mortises in which the bars pass through the stem; these wedges being drawn in, they will stick fast, and press against the bars, keeping them fast at all points, and thereby regulate the distance of the fence from the vertical side of the stock. This plane is generally employed to rebate narrow pieces of wood, such as fastenings; and the fence is applied against the opposite edge of the wood to that on which the rebate is to be formed.

The *plough* is a plane with a very narrow face, made of iron, fixed beneath a wooden stock, and projecting down from the wood of the stock, the edge of the iron being the full width, or rather more, than the face; it is guided by a fence with two bars, like the fillister above described, to make or plough out a groove of the width of the iron, and at any required distance from the edge of the wood; it has also a similar stop to regulate the depth it cuts to.

Plane for planing surfaces of Metal.—This tool has been brought into use within these few years past, to the great improvement of the work of those artists who employ it. These are chiefly the mathematical instrument-makers who are in the constant habit of having to make straight rulers in brass, and prepare work requiring very flat surfaces, such as the limbs of sextants, &c.; but all trades which work in brass and iron, would find their advantage in employing the plane. The stock of this plane is usually made of cast-iron, in form of a hollow box, the bottom, sides, and ends being all cast in one piece; it is usually 12 inches in length, $1\frac{3}{4}$ in height, and $1\frac{1}{2}$ in breadth across the face; the iron is situated at about four inches from the fore end, not inclined, as in other planes, but held in a perpendicular direction, with its lower or cutting edge passing through the mouth, and pro-

jecting the least possible quantity beneath the surface of the face, but leaving only so small a space before the edge for a mouth, as will but just admit a piece of thick paper; the iron is held against a brass frame fixed across in the hollow of the box or plane, and containing within it a screw, on which a nut or slider is fitted, to rise and fall when the screw is turned round by a milled head upon the upper end of it; the nut or slider has a projecting pin, which enters into a round hole made through the iron; and in this case, by turning the screw, the iron is raised or depressed, to cause the edge to protrude more or less beyond the face; to support this frame behind, a block of wood is fitted into the hollow of the stock, to fill up all the cavity, and it projects so much above as to form the handle for the plane.

In the front end of the stock a screw is tapped through its thickness, and acts against a piece of wood, which it presses up against the iron, and thus holds it fast against the brass frame, in the same manner as the wedge of a common plane; this piece of wood is formed forked and hollowed where it applies to the iron, to allow room for the chips to come up from the mouth. The workmen who use this plane call it *stripping*, instead of planing, brass or other metal.

The metal plane is used in the same manner as a carpenter's jack plane, but as the shaving it cuts, or rather scrapes off, must be exceedingly thin, the greatest nicety is necessary in adjusting the projection of the iron beyond the face; and for this reason the screw is essential.

The work is to be supported upon a firm bench, which is best made of cast-iron, and the surface of it made perfectly flat, which is done by grinding the face of the plane against it with emery, till both are true. The front face of the iron is quite flat, and perpendicular to the face; the edge is formed at the bottom of this surface by grinding a bevel from the back at an angle of about 45 degrees; the edge is then made fine by a Turkey stone. The iron must be exceedingly hard and of the very best steel, and then the plane will cut soft steel, bell-metal, or *cast-iron*, as well as brass, to very good purpose. When the work is rough, it is difficult for a man to work the plane, if set coarse for expedition, they therefore use, in such case, an iron which is cut with flutes on the front side, and then the edge will be divided into separate teeth, which scrape and cut away with less resistance than a complete edge. Messrs. Holtzapffel and Deyerlien of Cockspur-street, make these planes for metal of exceedingly hard cast-iron, and very true faces, which do not therefore become scratched or injured by wear. It should have been mentioned before, that joiners, cabinet-makers, &c. in planing thin or valuable woods for veneering, &c. sometimes use fluted irons, having teeth in their edge; and a plane thus mounted is called a *toothed plane*; these irons apply to the stocks of different planes.

Planing machines

PLANING MACHINES, are machines used to diminish the great manual labour of planing the surface of planks and boards of wood: in strictness, those alone should be termed planing machines, which operate to reduce the surface of the wood to a true and smooth plane, by means of planes or instruments of a similar nature, though actuated by the power of machinery instead of the strength of a man's arm; but custom has denominated those machines which cut flat surfaces in a different manner from planes by the same name.

These machines are of modern invention; the first, we believe, was projected by general Bentham, who obtained a patent for it in 1791. It consisted of a plane, to be put in motion by means of a crank turned by a mill, to give it a reciprocating motion; or on a smaller scale it might be worked by hand in the usual manner, but the plane was so formed as to require none of the skill and attention necessary in the ordinary method of operating: here the workman, besides exerting the force necessary to force the instrument along, has several points to attend to, even in the simple case of planing a straight board he must adjust his tool to the board in a proper manner for beginning the stroke, and employ sufficient force to keep it down to the board; and in returning, he must raise it up off the board sufficient to save the cutting edge from injury; he must also guide it sideways to prevent it slipping off the board, and if this is wider than the plane, he must constantly examine if he reduces the middle and the sides in a proper manner to make a plane surface; and, lastly, he must observe the marks he previously makes for the thickness of the board, that he may keep it parallel, and not reduce it too thin. By the general's invention all these circumstances are gained at once; the plane is made the full width of the boards intended to be planed, and on each side of it fillets or cheeks are fixed, which project beneath the face of the plane just as much as the thickness the board is to be reduced to: these cheeks, therefore, guide the plane sideways in passing along the board, and gauge it in thickness; because, when the board is reduced to the quantity which the cheeks are beneath the surface of the plane, the cheeks rest upon the bench or surface on which the board lies, and bear off the plane, so that it can cut no longer. The plane is kept down by its own weight, which is increased, when necessary, by loading it with weights, and these are contrived to be capable of shifting their position from one end of the plane to the other during the time it is making the stroke; because, at first the pressure is required at the fore end to enter the cut, but at the con-

clusion it must be greatest at the hinder end, to prevent the fore end tripping down the instant it leaves the board. By another contrivance the plane is caused to rise up sufficiently to clear the cutting edge from the wood when the plane is on its return. It is by a piece which acts as a handle to the plane, and to which the power is applied, that it is fixed in the manner of a lever upon an axis extending across the width of the plane, and carrying at each side thereof a short lever, provided with rollers in their extremities; the handle projects upwards from the plane, which being forced forwards by it, assumes an inclined position, as do also the short levers, and their rollers then rise above the cheeks of the plane; but when the plane is drawn back, its handle is first drawn back into an erect position, and the levers moving with it, their rollers project beneath the cheeks of the plane, and raise it off the bench, the plane being in its return borne by them.

The bench for supporting the board during the operation was also of a peculiar construction, in order to confine the work steady upon it. In cases when the boards to be planed are winding or irregular on the lower side, so that they cannot lie flat upon the bench, it is provided with two sides, which can be brought to close upon the edges of the board, and hold it steady between them, being furnished with one or more rows of flat teeth to penetrate the wood and retain it; these sides are contrived to rise or fall upon the bench, to accommodate the different thicknesses of the boards. When a very thin board is to be planed, it might be liable to spring up to the iron, so as to be reduced even after the plane came to rest with its cheeks upon the bench; to avoid this the edges of the board are to be held by the sides to the bench above-mentioned, but as it would still be liable to spring up in the middle part, heavy rollers, or rollers loaded with weights, are fitted in apertures made in the plane as near as possible to the cutting edge, and these will keep the board down close upon the bench. For planing pieces of greater thickness at one end than the other, the cheeks of the plane are to be borne upon rulers of wood laid on the bench on each side, the wood being as much thicker at one end as the board is intended to be thinner at that end; therefore, when the plane has reduced the wood, the cheeks come to bear upon these rulers, and cause it to move not parallel to the bench, but inclined, according as they are thicker at one end than the other: in like manner, by using them of different thicknesses at the different sides the boards may be made feather-edged.

Mr. Bramah invented a planing machine, which he has

used very advantageously for planing all kinds of timber flat, at an exceedingly small expence. In 1802 he took out a patent for the invention, which he describes in his specification to consist in the following particulars. "The cutting tools employed to reduce the wood, instead of being worked by hand are to be fixed on frames, some of which are moved in a rotatory direction round an upright shaft, and others have a shaft lying in a horizontal position like a common lathe. In other instances, the tools are fixed on frames, which slide in stationed grooves to be driven also by machinery. The principal points on which the merits of the invention rest are, 1. The materials to be wrought are made to slide in contact with the tool, instead of the tool being carried by the hand over the work in the usual way. 2. The tool is made to travel across the work in a square or oblique direction, except in cases where it may be necessary to fix the tool in an immoveable station, and cause the work to fall in contact with it by a motion. 3. Instead of common tools, bent knives, spoke shaves, or deep cutting gouges, are used for cutting off the roughest parts, and planes of various shapes and constructions, as the work may require, are applied to follow the former in succession, under the same operation, and which latter I call finishers. 4. These are fixed on frames which move in cases, like those on which the saws are fixed in a sawing-mill, and in other instances these frames are fixed on a rotatory upright shaft turning on a step, and carrying the frame round in a direction similar to the upper mill-stone for grinding corn, and sometimes the frames turn on a horizontal shaft, resembling the mandrel of a common turning lathe. The different planes, tools, &c. are fixed in the frames, so as to fall successively in contact with the wood or other materials to be cut, so that the cutter or tool calculated to take the rough and prominent part operates first, and those that follow must be so regulated as to reduce the material down to the line intended for the surface. These cutter frames must also have the property of being regulated by a screw, or otherwise, so as to approach nearer the work, or recede at pleasure, in order that a deeper or shallower cut may be taken at discretion, or that the machine may repeat its action, without raising or depressing the material on which they act. 5. When an upright shaft is used, the pivot is to turn in oil, and it may be raised or depressed at pleasure, by means of a greater or less quantity of the said fluid being confined between the end of the shaft and the bottom of the step. 6. The materials to be cut must be firmly fixed on a frame, similar to those in sawing-mills, on which the timber is carried to the saws. These frames must be moved in a steady progressive manner as the cutter frame turns round, either by the same power which moves the latter, or otherwise, as may be found to answer best in practice. 7. The motion of the cutter frames must be under the controul of a regulator, so that the velocity of the tool, in passing over the work, may be made quicker or slower as such work may respectively require, to cause the cutter to act properly to the best advantage." For this purpose Mr. Bramah proposes to use what he calls a universal regulator of velocity, and which he describes as follows: "I take any number of cog-wheels, of different diameter, with teeth that will exactly fit each other through the whole; suppose ten, or any other number, but for an example say ten, the smallest of which shall not exceed one inch in diameter, and the largest suppose ten inches in diameter, and all the rest to mount by regular gradation in their diameters from one to ten. I fix these ten wheels, fast and immoveable, on an axis perfectly true, so as to form a cone of wheels; I then take ten other wheels, exactly the

same in all respects as the former, and fix them on another axis, also perfectly true, and the wheels in perfect gradation also; but these latter wheels I do not fix fast on their axes, like the former, but leave them all loose, so as to turn upon the said axes, contrary to the former, which are all fixed. All these latter wheels I have the power of locking, by a pin or otherwise, so that I can at discretion lock or unite any single wheel at pleasure to the axis. I then place the two axes parallel to each other, with the wheels which form the two cones as above described, in reverse position, so that the large wheel at one end of the cone may lock its teeth into the smallest one in the cone opposite, and likewise *vice versa*. Then suppose the axis, on which the wheels are permanently fixed, to be turned about all the wheels on the other axis will be carried round with velocities corresponding to their diameters and those of the former, but their axes will not move. Then lock the largest wheel on the loose axis, and by turning about the fastened axis, as before, it must take ten revolutions, while the opposite wheel performs but one; then by unlocking the largest wheel, and locking the smallest one at the contrary end of the cone in its stead, and turning as before, the fastened axis will then turn the opposite ten times, while itself only revolves once. Thus the axes or shafts of these cones, or conical combinations of wheels, may turn each other reciprocally, as one to ten, and ten to one, which collectively produces a change in velocity, under an uniform action of the primum mobile, as ten to a hundred; for when the small wheel on the loose axis is locked, and the fast one makes ten revolutions, the former will make one hundred; and by adding to the number of these wheels and extending the cones, which may be done *ad infinitum*, velocities may be likewise infinitely varied by this simple contrivance: A may turn B with a speed equal to thousands or millions of times its own motion; and by changing a pin and locking a different wheel, as above described, B will turn A in the same proportion, and their power will be transferred to each, in proportion as their velocities reciprocally. Here is an universal regulator at once for both power and velocity. In some instances I produce a like effect, by the same necessary number of wheels made to correspond in conical order, but instead of being all constantly mounted on the axes or shafts, as above described, they will reciprocally be changed from one axis to the other, in single pairs, to match according to the speed or power wanted, just as in the former instance. This method will have, in all respects, the same effect, but not so convenient as when the wheels are all fixed."

The utility of Mr. Bramah's machine, not less than its ingenuity, has induced us to procure drawings of one of them, which he has in constant use in his factory at Pimlico. It is upon exactly the same construction as one he made for the royal arsenal at Woolwich, by which all the timber for gun-carriages, and other similar articles, is now planed at a trifling expence, compared with the old method of planing by hand labour. See *Plates I. and II. Planing Machine*, where *fig. 1.* is a plan of the whole machine, and *fig. 2.* an elevation thereof; *A a* is a vertical axis, put in motion by a steam-engine, the power being communicated to it by a pair of bevelled wheels *B*, one fixed on the vertical shaft, and the other at the extremity of a horizontal spindle *C*, *fig. 1;* see also *fig. 8. Plate II.* which has a live and dead pulley upon it at *c*, for the reception of an endless strap, by which the machine is driven. The shaft *a A* is for the purpose of carrying an iron wheel 33, shewn separate in *fig. 3;* it has the cutters fixed at the different points 7, 7, 7, 7, of its circumference;

these are six in number at each side, and are formed with cutting edges similar to gouges or scoops (see *fig. 7.*); at the two opposite points, 4 and 5, it has small planes fixed in its rim, as shewn separate in *figs. 4 and 5*: when this wheel revolves, its cutters will cut away all which projects above the plane of their motion; the wood is carried under them with a progressive motion, upon two moveable carriages E E and E E, one at each side of the wheel, and moving in opposite directions; they traverse upon iron beds, or railways F, F, which are more than double the length of the carriages: these are supported on iron legs, from a foundation of masonry, and well united together by cross pieces D, D, to keep them always in one plane, for upon this circumstance the truth of the planing depends. The pieces of wood to be planed are fixed down upon the carriages at G, G, and held firmly by screw-clamps with proper contrivances; the machine is then put in motion, and at the same time that the wheel is revolving the carriages are both drawn in opposite directions beneath its cutters, which soon clears away the wood to a perfect plane, by making successive strokes obliquely across the wood, and as the carriages advance these strokes proceed in succession from one end of the piece to the other. The gouges 7, 7, act first to chop, or hew away the wood roughly, but to a flat surface, and then the planes 4, 5, follow and reduce it to a smooth plane: this is accomplished by their being placed rather nearer the centre, so that they revolve in a rather smaller radius, and thus act upon the wood after the gouges have finished. We shall now enter more minutely into the details of the machinery: the two carriages E, E, are put in motion alternately, by means of an endless chain H H, which is extended between two horizontal wheels K, I; the centre pin of the latter is fixed in a piece of wood d, fitted in a groove formed between the two adjacent rails F, F, on which the carriages run; the slider has a screw b, by which it is forced outward, and thus strains the chain between the two wheels so tight, that when the wheel K is turned round, it will draw the chain, which being connected with the carriages beneath, gives them both a progressive motion. The wheel K is fixed upon a short vertical axis, upon the lower end of which is a pinion L, having its teeth engaged with a rack M, attached to the piston-rod of a cylinder 10, situated horizontally on the ground (see also *fig. 10. Plate II.*): the piston-rod, M, is fitted through a stuffing-box, e, at the end of the cylinder, and the piston, f, is fitted accurately to the chamber with leathers, to make it perfectly water-tight: the cylinder is bolted fast down upon the floor framing, as shewn in both figures, and pipes g, h, enter into it at each end, for the purpose of introducing or returning water, which acts upon the piston f, to give it an advancing or retrograde motion, upon the hydrostatic principle invented by Mr. Bramah, and described at the end of our article MACHINERY; see also PRESS, *Hydrostatic*. The steam-engine which gives power to the whole machine also works a small forcing pump, or injector, which is constantly pumping water into an air-vessel, under a great pressure: from this small copper pipes are conducted to the machine, to operate, when required, either in the cylinder 10, or in another, which is the step, or support of the main vertical shaft, and gives the means of raising or lowering it with the wheels and cutters all together, to cause them to reduce the wood upon the bench to any required thickness. The admission of the water into these cylinders is regulated by cocks, situated at one side of the machine, in a position where a person can, at the same time, manage them, and have a complete view of all the machine, to watch its operation. The relative position of these cocks

is shewn in *fig. 8*, where that for the service of the cylinder is marked N, and the other for regulating the thickness is marked O, and i is the pipe leading from it to the bottom of the cylinder 13; the cocks themselves are shewn on a large scale in *figs. 11 and 12*: the entry pipe, which brings the water from the injector, is here plainly shewn, with two branches leading to the cocks. From the cock N, a passage directly opposite to the entry leads to the waste, or escape-pipe; and on the two opposite sides, at right angles to the former, are pipes g and h, leading to the front and back of the cylinder: the cock itself has two curved passages through it, which will make communication with any two adjacent pipes of the four; thus, as it stands in the figure, the water from the entry passes to the back of the cylinder, whilst the water contained in the front end is at liberty to escape at the waste pipe. In this situation the piston is moved towards the front end of the cylinder, and turning round the pinion and wheel K, (*figs. 1 and 2.*) moves both carriages in one direction: now by turning the cock N a quarter of a revolution in either direction, the same passages make a different communication, viz. from the entry to the front of the cylinder, and from the back to the waste; this throws the action upon the front side of the piston, drawing it to the back end of the cylinder, and moving the carriages in an opposite direction. By turning the cock only $\frac{1}{4}$ th instead of $\frac{1}{2}$ th, all the four passages are close stopped, and no motion takes place. The other cock, O, is more simple; thus, the entry is on one side, the pipe i at right angles to it, and the waste opposite the latter; the passage in the turning part of the cock is made diametrically through it, and another at right angles into it. In the position of the drawing, the pipe, i, is open to the waste, and permits the water in the cylinder 13 (*fig. 8.*) to escape; but when the cock is turned round one-fourth, to bring the short passage opposite the pipe i, a fresh supply of water will be admitted from the entry into the cylinder 13, or, by turning a little farther, all of them are shut. The cylinder marked 13 (*fig. 8.*) is fixed by screws in the middle of one of the cross bars D; it is accurately bored within, and fitted with a piston P, (see also *fig. 13.*) which is packed with leather cups, so that no leakage can take place by the side of it; in the upper side of the piston is a perforation for the reception of a steel pivot, which is fixed in the lower end of the great vertical spindle A, and thus supports its weight as it revolves; the upper end, a, of the great spindle is fitted through the centre of the cog-wheel, B, with a fillet, so that it has free liberty to rise and fall, but cannot turn round without the wheel; the wheel itself is supported by means of a cone formed on the lower part of it, and fitted into a socket supported at the top of four iron standards Q, Q, which are erected from the iron framing below, and thus they sustain the axis and wheel very firmly from the same frame as the rails F, F, which support the carriages. At the top of the vertical spindle a shackle, a, is fitted, by a pin with a head, inserted into the end of the axis, and retained by a cross pin; by this means the shackle is united to the spindle, to rise and fall with it, but not to revolve with it; a chain is attached to the shackle, and passes over a pulley, as shewn at m, in *fig. 2.* and thence to a small pulley n; to this is attached a larger wheel, o, from which a chain is carried, to suspend a heavy wooden ruler p, situated at some distance from the machine, and sliding in a groove; it has divisions shewing inches and parts graduated upon it, which are determined by an index fixed to the wood of the groove. On this scale, those divisions which are marked inches are three times that length, because the wheels n and o are as three to one in dia-

meter : this scale shews the thickness to which the machine will reduce the wood upon the carriages, the index being so adjusted that it stands at zero of the scale when the wheel 3 3 is lowered down till its cutter cuts the surface of the carriage ; then by turning the cock N, the water is very gradually admitted into the cylinder 13, and elevates the piston P, the shaft, and wheel altogether, to any required height above the bench, which is shewn in inches and parts by the scale to very great accuracy ; for by the cock being very partially opened, the wheel rises so slowly, that it can be adjusted to the greatest nicety. The wheels *n* and *o* are supported in the floor above the room, as is also the frame for the support of the axis, C, of the live and dead pulley *c* ; the endless strap of this pulley is guided through an eye at the end of an iron rod *s*, fig. 8, which is joined to a lever T, coming down in reach of the attendant, who also manages the cocks N, O.

The construction of the cutters is shewn in fig. 7 : here 3 is a section of a part of the rim of the wheel, and *t* an iron clamp screwed fast down upon it, as shewn in fig. 3 ; the clamp has a vertical mortise through it for the reception of the stem of the gouge cutter 7, which is fixed fast therein by a wedge piece and screw *v* : by this means they can all be adjusted till their edges come exactly into one plane, though not quite so deep as the faces of the planes : these are made, as shewn in figs. 4 and 5, in iron, being received into an opening in the rim of the wheel, and held fast by two bolts, *w, w*, with keys above the surface of the wheel to keep them fast ; the plane iron, *x*, is double, and fixed into its place by an iron wedge *y*, formed similar to that of a carpenter's plane.

It only now remains for us to explain the construction of the dogs or claws for holding the work fast down upon the benches E, E ; these are of two kinds, some fixed on the outsides of the carriage, and others in the middle, which draw up by screws to hold the wood fast ; the carriage is composed of two large beams E, E, fig. 9, which is a cross section of it ; these are united by proper cross pieces, and run upon the rails F, F, with metal pieces fixed on the lower sides of them. There are also several cast-iron frames fixed across, as shewn by the dark shaded parts *k* ; each consists of two cheeks, all formed from one piece, and leaving a groove between them ; in this groove a long screw, *h*, is fitted by a collar at one end, and operates upon a slider, 8, fitted into the groove ; a dog marked *z*, and bent something like an S, is attached to this slider, and projects above the bench, having a sharp point which penetrates the wood 2 G, and forces it against the other claws, *r, r*, fixed on the outsides. When the wood, as G, fig. 9, is of small size, another small claw, 9, is applied ; this is screwed into a nut of brass, which is fitted into the groove, then a second piece of wood, 2, is applied between it and the dog *z*, to transmit the force of the screw, *h*, to the other one at 9 : the outside claws, *r, r*, are formed on the top of square stems, which are fitted through clamps affixed to the sides of the carriages, as shewn in fig. 6, and provided with clamp screws, by which they can be fixed at any required height. The dogs *z* are very simply attached to the nut 8, by being applied upon the flat top surface of it, and one point enters into a small hole made in the fore part of the nut 8 ; by this means it is simply hooked into its place, and when the screw is turned, it cannot get loose ; another advantage is, that the clamp may be reversed, or turned the other way, and then the screw can be employed to hold the wood between *z*, and the claws, *r*, of the opposite side of the carriage. By these means the bench will hold a large piece of wood of the full width of the bench, or by introducing one of the clamps, 9, between each piece, it will hold as many narrow ones as will make

up the width, and they will be all planed together to one surface.

The endless chain H, which gives motion to the carriages, is connected with them by means of a piece of wood H, fig. 9, projecting down from it, and divided into two halves, between which the chain can be clamped or jammed fast when they are drawn together by a screw 6 ; therefore, by relieving this screw, the two halves open so much, as to permit the chain to slide freely between them ; in this case the carriage will stand still. This expedient is used when it is required to have one carriage disengaged, for, in general, both are used together, in the following manner ; suppose both carriages at the ends of their respective rails, the wood is laid upon them, and by the screw 6, which is turned with a winch, it is clamped fast on the chain. If the wood is winding, or irregular, it is made up at first by wedges, till its upper surface is parallel to the bench, and it is then fixed by the screws *l* ; the carriages are then engaged with the chain, by turning the handle of the screw 6, which for that purpose comes to the outside. Next the cock O is turned one way or the other, to raise or lower the cutter, till the gauge, *p*, shews it to be at the thickness the stuff is to be planed to. All being thus prepared, the handle of the lever, T, is drawn ; this draws the strap upon the live pulley *c*, and puts the machine in motion, and having acquired its full velocity, the same person turns the other cock N, and gently opens it ; this puts the carriages in motion, and he can, by regulating the handle of the cock, give it any velocity he wishes ; he can bring it up very quick, till the work comes under the cutters, and then move it very slowly, if much wood is to be reduced, or quicker when but little is to be taken off. In this manner the planing is performed from one end of the piece to the other, and the successive strokes of the cutters and planes follow each other so closely, as to leave an even surface, and with only such very slight scores across it, that the least shaving of a smoothing plane afterwards finishes it, from the roughest and most irregular timber which can be found.

In 1803, Mr. Bevans obtained a patent for a machine which we have seen at work for planing (or *sliding*, as the joiners term it) all kinds of mouldings or rebates, and ploughing grooves, as well as forming flat surfaces of small breadth, which it does with very little labour : in this machine, these operations are performed by the planes commonly used for similar purposes, with only such alterations as are necessary to adapt them to the machinery by which they are put in motion with mechanical power instead of human labour ; they are to be used either singly, or combined together in any number, according to the width of the boards to be worked at once, and the nature of the work to be done, so as to plane up at one operation such moulding as joiners work up by using several planes successively for the different parts ; this is effected by a kind of frame or box, which admits of fixing any number of planes in it, side by side, and at any distance asunder, to form the compound moulding required. The work is fixed fast on a bench, and the box of planes is made to pass over it, in the direction of its length, by a connecting rod communicating at one end with the box or frame containing the planes, and at the other end with machinery capable of affording a reciprocating motion.

This machinery consists of a crank, whose radius must be nearly half the length of the required stroke, and must be regulated accordingly : this regulation is effected by the arm of the crank passing through a mortise in a strong box, fixed on an axis, and sliding in the said box to any required length, where it must be fixed by strong screws, the axis being turned by manual exertion, by horses, steam, water, or any

other power, and having its motion regulated by a fly-wheel.

The planes are loaded, to keep them in contact with their work, by a long beam of wood, set up on end upon the sides of the box, and connected therewith by being divided into two cheeks, which at the lower sides are formed to an arc of a circle, and united to the box by chains, in the same manner as the beams of steam-engines are connected with their piston-rods. The upper part of the beam is made to pass always through one point by sliding between friction-wheels, or otherwise in a tube hung on two pivots perpendicularly over the centre of the work, and at such heights as

may be most convenient for the length of the stroke required: the connecting-rod from the crank before mentioned is jointed to the upright beam, near its lower end, and by this means the motion is given to the box of planes, the chains and arches at the bottom allowing it in all positions to preserve the plane horizontal. To guide the box of planes in a rectilinear motion, and also to bear them off when they have been reduced to the depth required, fences are used, which are irons sliding perpendicularly in tubes or sockets in the box or frame, and clipping a tongue, or ruler fixed in the direction of the required stroke, in the frame supporting the bench.

PLANES 1 & 2.

W. Loomis's Planing Machine.

Fig. 7



Plan.

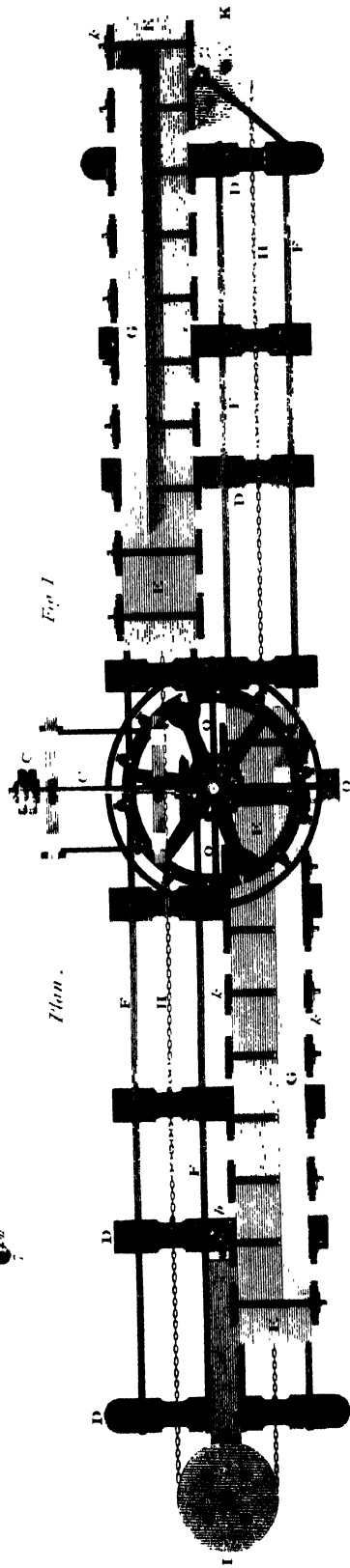
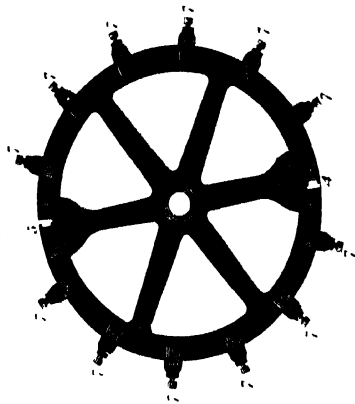


Fig. 1

Fig. 1.



Fig. 3.



Elevation

Fig. 2.

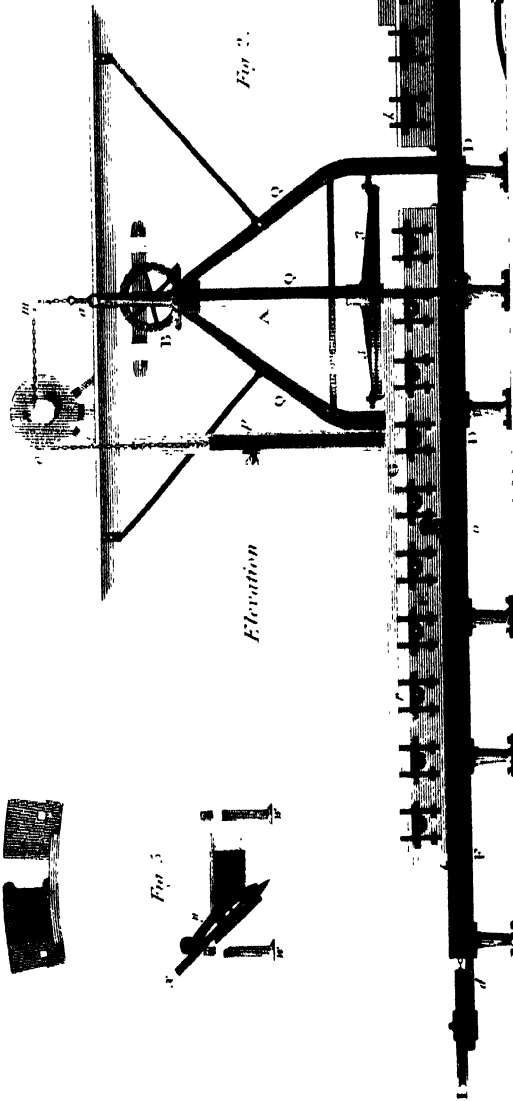


Fig. 5



PLANING MACHINE.

Mr Bramah's Planing Machine.

cross section

Fig. 9.

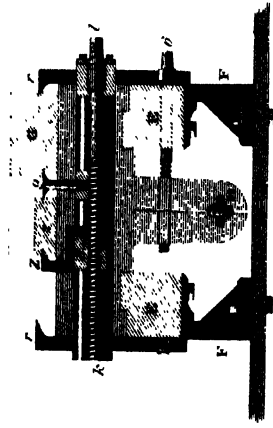
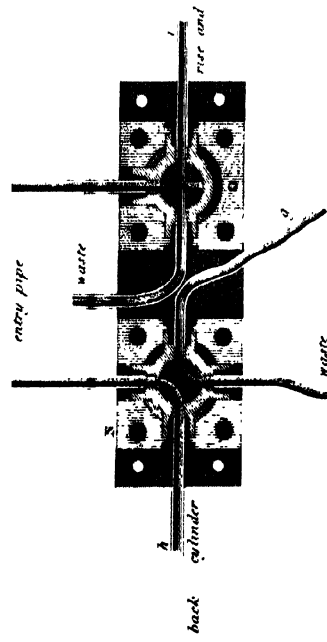
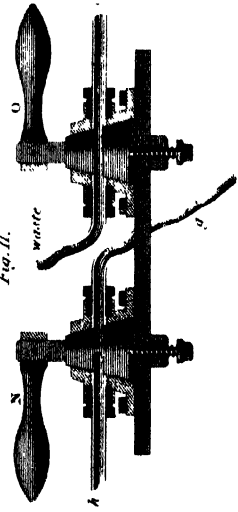


Fig. 1.



Locks.

Fig. 11.



cylinder.

Fig. 10.

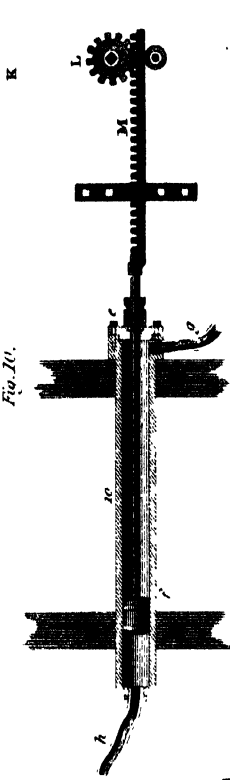
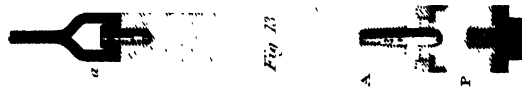
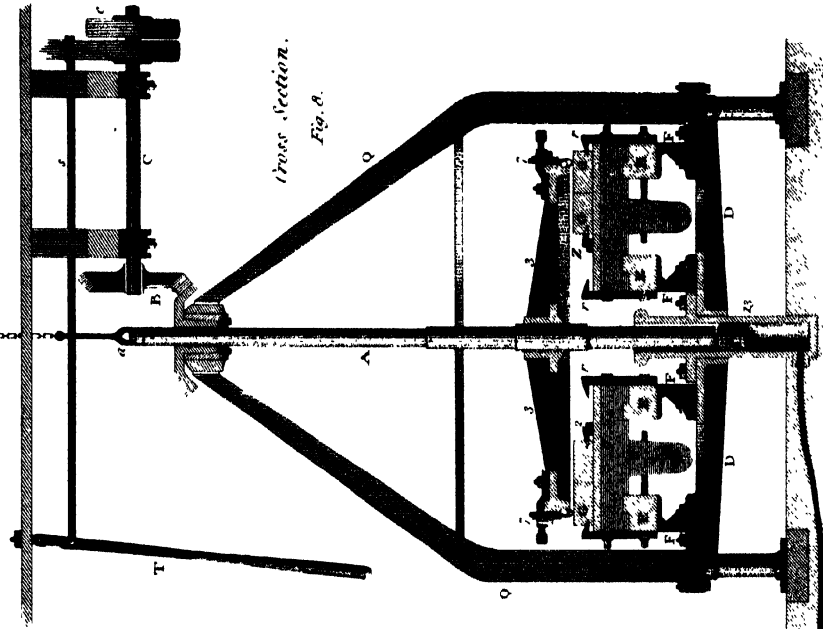


Fig. 23.



cross section.

Fig. 8.



back cylinder
waste pipe
front of cylinder

Plaster

PLASTER, or **PLAISTER**, in *Building*, a composition of lime, sometimes with hair, sometimes with sand, &c. to parget or cover the nudities of a building.

There is also a plaster of a coarser sort than the plaster of Paris, which is sometimes used in this country for floors in gentlemen's houses, and for corn-granaries: it is made of a bluish stone, taken out of quarries, which are generally at the side of a hill, much like the stone of which Dutch terras is made: the stone is burnt like lime, becomes white by burning, and when mixed with water, does not ferment like lime: when cold, it is beat into a fine powder; and when it is used, the quantity of about a bushel is put into a tub, and water applied to it, till it becomes liquid: in this state it is well stirred with a stick, and used immediately; for in less than a quarter of an hour it becomes hard and good for nothing, as it will not bear being mixed a second time like lime. See **GYPSUM**, and **PLASTERING**.

PLASTER, in *Pharmacy*, an external application of a harder consistence than our ointments: these are to be spread according to the different circumstances of the wound, place, or patient, either upon linen or leather.

If the part upon which they are to be laid be naturally hairy, it must be shaved; but that they may stick the better, the natural shape of the part must be consulted, and the plaster spread and formed accordingly, either round, square, triangular, elliptical, in a lunar form, or in shape of the letter T. Some also are divided at both ends, and others are perforated in the middle: these last are of frequent use in fractures attended with a wound; for by this contrivance the wound may be cleansed and dressed without removing the plaster.

Indeed there is almost no part of the body which a plaster of one of those forms may not be made to serve for, if it be notched about the edges with a pair of scissors. See **EMPLASTRUM**.

The use of plasters is various; they are serviceable in securing the dressings, they also forward the maturation of the pus, agglutinate and heal wounds, unite broken bones, heal burns, assuage pain, and strengthen weak parts. In many instances they contain acrid and stimulating substances, and operate as rubefacients, or blisters.

The calces or oxyds of lead boiled with oils, unite with them into a plaster of a proper consistence, which makes the basis of several other plasters: but some of them owe their consistence to wax and resin; and others contain no oily or fatty matter whatever: in boiling these compositions, a quantity of hot water must be added from time to time, to prevent the plaster from burning and growing black; but this should be done with care, lest it cause the matter to explode.

Plasters should not adhere to the hand when cold; they should be easily spread when heated; and after they are spread they should remain tenacious and pliant; but they should not be so soft as to run when heated by the skin. All plasters become too consistent or brittle when long kept; but in this case, those which are unctuous may be remelted by a gentle heat, and some oil added to them. They are usually formed into rolls, each of which is wrapped in paper, and when used, they are melted, and spread on leather, calico, linen, or silk. Those that contain metallic oxyds ought to be melted by boiling water, for in a greater degree of heat the fatty matter is apt to reduce the oxyd.

PLASTER, Adhesive. See **EMPLASTRUM**.

PLASTER, Ammoniac, is formed by dissolving 5 oz. of purified ammoniac in half a pint of acetic acid (distilled

vinegar), and evaporating the solution in an iron vessel placed in a water bath; constantly stirring it till it acquire a proper consistence. This plaster, which is stimulant and resolvent, is applied to scrophulous humours, and white swellings, and sometimes over the scalp, in tinea capitis.

PLASTER, Ammoniac, with Mercury. See **EMPLASTRUM**.

PLASTER, Anodyne. See **EMPLASTRUM**, and **PLASTER of Opium**, infra.

PLASTER, Aromatic, is formed, according to the directions of the Dublin pharmacopeia, of frankincense, 3 oz.; yellow wax, $\frac{1}{2}$ oz.; cinnamon bark in powder, 6 dr.; oil of pimenta and oil of lemons, of each 2 dr. Melt the frankincense and the wax together, and strain the mixture; when it thickens by cooling, mix with it the powder of cinnamon previously rubbed with the oils, and form them into a plaster. This plaster is an elegant stimulant, and applied to the region of the stomach in dyspepsia, and increased irritability of that viscus, allays pain and vomiting, and expels flatus. As the oils are very volatile, it must be spread by the thumb without being melted. It requires to be frequently renewed, and is not very adhesive.

PLASTER, Asafetida, consists, by the Edinb. pharm., of plaster of semi-vitreous oxyd of lead, and asafetida, of each two parts, and galbanum and yellow wax, of each one part. This plaster is sometimes applied over the umbilical region, in flatulence and hysteria.

PLASTER, Blistering, Emplastrum Lyttae of the Lond. pharmac., is made by melting $1\frac{1}{2}$ lb. of wax plaster with a pound of prepared lard, and after removing them from the fire, when the mixture is beginning to be solid, sprinkling in 1 lb. of blistering flies reduced to a very fine powder, and mixing the whole together. The *emplastrum Meloe vesicatorii*, olim, *emplastrum vesicatorium* of the Edinb. pharm., consists of mutton suet, yellow wax, resin, and blistering flies, of each equal weights. Reduce the insects to a fine powder, and mix them with the other articles, previously melted together, and removed from the fire. The *emplastrum cantharidis* of the Dubl. pharmac. is formed by melting purified yellow wax and mutton suet, of each a pound, and 4 oz. of yellow resin together, and a little before they concreate in becoming solid, sprinkling in 1 lb. of blistering flies in fine powder, and forming the whole into a plaster. (See **EMPLASTRUM**.) Blistering plasters should remain applied at least for twelve hours to raise a perfect blister; they are then to be removed, the vesicle is to be cut at the most depending part, and without removing the cuticle, the vesicated part is to be dressed with simple cerate, or spermaceti ointment; and the old cuticle allowed to remain until a new one is formed under it; when it peels off, and the whole is healed in the course of a few days. The application of these plasters is sometimes attended with strangury and bloody urine, from the absorption of the active principles of the insect, and the irritation of the kidneys and urethra; and this effect is much increased, if the blister be applied over an abraded surface, e.g. on the head after it has been immediately shaved, and also if the plaster has remained too long applied. To prevent strangury, it has been recommended to mix camphor with the blistering composition, but this has no good effect; it is better obviated by copious dilution with milk, or mucilaginous fluids, and fomentations of warm milk and water to the blistered part, after the removal of the plaster. When the head is to be blistered, it should be shaved at least ten hours before the plaster is applied; and in all cases it is expedient to interpose a piece of thin gauze between the vesicatory and the skin, wetted with vinegar, and applied smooth and very close over the

PLASTER

plaster. When the blistered part becomes a spreading sore, which is sometimes the case in irritable habits, the best local application is a warm emollient poultice, and bathing the denuded surface frequently with tepid milk and water; while at the same time cinchona bark is internally administered. See BLISTER.

PLASTER of Spanish flies, compound, of Edinb. pharm., is prepared of 18 parts of Venice turpentine; Burgundy pitch and blistering flies, of each 12 parts; yellow wax, 4 parts; subacetite of copper, 2 parts; white mustard seeds and black pepper, of each 1 part. Melt the Burgundy pitch and the wax, and add to them the turpentine; while these remain still warm, after being melted, sprinkle in the other ingredients reduced to fine powder, and mix them, stirring constantly, so as to form a plaster. This plaster is intended to raise a blister more quickly than the former, and is therefore adapted to cases of gout and cramps of the stomach, in which the effect of the blister must be almost instantly produced. Its operation is attended with much pain and pungent sense of heat; and it is apt to produce very unpleasant ulceration if allowed to remain too long applied.

PLASTER, Cephalic. See *EMPLASTRUM Cephalicum*.

PLASTER, Common. See *EMPLASTRUM Commune*.

PLASTER, Cumin. See *EMPLASTRUM à Cymino*. This plaster is stimulant and discutient; and is applied to the hypogastric region in flatulence and a cold feeling of the bowels, and to indolent tumours.

PLASTER, Drawing. See *EMPLASTRUM Attrahens*.

PLASTER of Galbanum, Compound, of the Lond. pharm., is composed of purified galbanum, 8 ounces; plaster of lead, 3 pounds; common turpentine, 10 drachms; and resin of the spruce fir powdered, 3 ounces. Having melted the galbanum and the turpentine together, mix in first the resin, and then the plaster of lead previously melted by a slow fire, and mix the whole together. The plaster of galbanum of the Dub. pharm. is prepared by adding to $\frac{1}{2}$ lb. of galbanum melted by heat, 2 lbs. of litharge plaster, and 4 oz. of yellow wax sliced; and then melting the whole together by a gentle heat.

PLASTER, Gum, of Edinb. ph., is composed of 8 parts of plaster of semi-vitreous oxyd of lead, and ammoniac gum-resin, galbanum, yellow wax, of each 1 part. See *EMPLASTRUM Gummi*.

These plasters are stimulant and suppurative. They are applied with advantage to scrophulous tumours; to joints which have been long affected with arthritic pains; and to the loins in rickets. As a suppurative, they are applied to indolent tumours, and to reduce the induration which often remains round abscesses, after they are discharged.

PLASTER, Mercurial. (See *EMPLASTRUM commune cum Mercurio*.) The Edinb. pharm. directs it to be prepared of olive oil and resin, of each 1 part; mercury, 3 parts; plaster of semi-vitreous oxyd of lead, 6 parts; rub the mercury with the oil and the resin, previously melted together and cooled, until the globules disappear; then add gradually the plaster of semi-vitreous oxyd of lead melted, and let the whole be carefully mixed together. These plasters are powerful discutients, and are applied to buboes, venereal tumours, nodes when they are not very painful to the touch, and indurations; they are also applied to joints affected with obstinate syphilitic pains.

PLASTER of Opium, consists of hard opium powdered, $\frac{1}{2}$ oz.; resin of the spruce fir powdered, 3 oz.; lead plaster, 1 lb.: melt the plaster and the resin together, then add the opium, and mix the whole. This plaster is said to be anodyne, and useful in relieving rheumatism and local pains.

PLASTER of red oxyd of Iron of Edin. pharm., formerly

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strengthening plaster, is composed of plaster of semi-vitreous oxyd of lead, 24 parts; resin, 6 parts; yellow wax and olive oil, of each 3 parts; and red oxyd of iron, 8 parts; rub the red oxyd of iron with the oil, and add the other ingredients melted.

PLASTER of Frankincense of Dubl. pharm. is formed of litharge plaster, 2 lbs.; frankincense, $\frac{1}{2}$ lb.; and red oxyd of iron, 3 oz.; to the frankincense and plaster melted together add the oxyd, stirring them together so as to form a plaster. These plasters are supposed to be tonic; and are used in muscular relaxations, and weaknesses of the joints after sprains; but they act chiefly in affording a mechanical support to the parts. See *EMPLASTRUM Roborans*.

PLASTER, Compound pitch, is composed of dried pitch, 2 lbs.; frankincense, 1 lb.; yellow resin and yellow wax, of each 4 oz.; and expressed oil of nutmeg, 1 oz. To the pitch, resin, and wax, melted together, add first the frankincense, then the oil of nutmeg, and mix the whole. This plaster is stimulant and rubefacient. It is used in catarrh, and other pulmonary affections, applied to the thorax; and in head-ache, and chronic ophthalmia, applied to the temples. When a serous exudation takes place, the plaster should be frequently renewed.

PLASTER, Head, is prepared by boiling together over a slow fire, of semi-vitreous oxyd of lead, rubbed to a very fine powder, 5 lbs.; olive oil, a gallon; water, 2 pints, stirring constantly until the oil and oxyd of lead cohere into the consistence of a plaster. It is necessary, however, to add a little boiling water, if the whole of that which was employed at first shall be consumed before the end of the process.

PLASTER of semi-vitreous oxyd of Lead, formerly common plaster, is prepared of the semi-vitreous oxyd of lead, 1 part; and olive oil, 2 parts; having added some water, boil them, stirring constantly, until the oil and the oxyd unite into a plaster. See *EMPLASTRUM*.

PLASTER, Litharge, of Dub. ph., is prepared by mixing 5 lbs. of litharge in fine powder; 9 lbs. of olive oil, and 2 pints of boiling water, at a high temperature, constantly stirring until the oil and the litharge unite so as to form a plaster, supplying occasionally any waste of water that may take place. These plasters are intended chiefly to defend excoriated surfaces from the action of the air, and to form the basis of some other plasters.

PLASTER, Resin, is formed of yellow resin, $\frac{1}{2}$ lb., and lead plaster, 3 lbs.; melt the lead plaster by a gentle heat; then add the resin in powder and mix.

PLASTER, Resinous, formerly adhesive plaster, is composed of plaster of semi-vitreous oxyd of lead, 5 parts, and resin, 1 part.

PLASTER with Resin, Litharge, is formed by melting $3\frac{1}{2}$ lbs. of litharge plaster by a moderate heat, and adding $\frac{1}{2}$ lb. of yellow resin finely pulverized, that it may melt quickly, and form a plaster. (See *EMPLASTRUM Adhesivum*.) These plasters are defensive, adhesive, and gently stimulant; they are used for retaining together the lips of recent wounds, when it is proposed to heal them by the first intention; to give support to ulcerated parts; and to assist their granulation and cicatrization.

PLASTER, Soap. (See *EMPLASTRUM Saponis*.) The soap plaster of the Edinb. pharm. is composed of 4 parts of semi-vitreous oxyd of lead; 2 parts of gum plaster, and 1 part of soap sliced. Mix the soap with the plasters melted together; then boil them a little so as to form plaster. Soap plaster is discutient, and is applied to lymphatic tumours; but it is much less useful than the mercurial plaster.

PLASTER, Stomachic. See *EMPLASTRUM Stomachicum*.

PLASTER, Warm, is made by melting together, over a gentle fire, one ounce of gum plaster, and two drachms of blistering plaster; or one part of plaster of cantharides, and seven parts of Burgundy pitch, according to the Dublin pharmacopeia. This is useful in catarrh, whooping-cough, the sciatica, and other fixed pains of the rheumatic kind. It ought, however, to be worn for some time, and to be renewed, at least, once a week.

PLASTER, Wax, is formed by melting together of yellow wax and of prepared suet, of each three pounds; and yellow resin a pound; and then straining. The *simple plaster*, formerly *wax plaster* of Edinburgh pharmacopeia, is formed of yellow wax, three parts; mutton suet and resin, of each two parts. These were generally used instead of the melilot plaster, as a proper application after blisters, and in other cases where a gentle digestion is necessary; but on account of the pain and irritation they occasion, they are now seldom employed.

PLASTER of Paris, is a fossil stone, serving many purposes in building; and used likewise in sculpture, to mould and make statues, basso relievos, and other decorations in architecture.

It is dug out of quarries, in several parts of the neighbourhood of Paris; whence its name. The finest is that of Montmartre. See GYPSUM.

Plaster of Paris, among our workmen, is of two kinds, viz. *crude*, or in the stone, and *burnt*, or beaten.

The *crude* is the native plaster, as it comes out of the quarry; in which state it is used as shards in the foundations of buildings.

The *burnt* plaster is a preparation of the former, by calcining it like lime in a kiln or furnace, and then beating it into powder, and diluting and working it. In this state it is used as mortar, or cement, in building.

This, when well sifted, and reduced into an impalpable powder, is used also to make figures, and other works of sculpture; and is, besides, of some use in taking out spots of grease, &c. in stuffs and silks.

The method of representing a face truly in plaster of Paris is this: the person, whose figure is designed, is laid on his back, with any convenient thing to keep off the hair. Into each nostril is conveyed a conical piece of stiff paper, open at both ends, to allow of respiration. These tubes, being anointed with oil, are supported by the hand of an assistant; then the face is lightly oiled over, and the eyes being kept shut, alabaster fresh calcined, and tempered to a thinish consistence with water, is by spoonfuls nimbly thrown all over the face, till it lies near the thickness of an inch. This matter grows sensibly hot, and in about a quarter of an hour hardens into a kind of stony concretion; which being gently taken off, represents, on its concave surface, the minutest part of the original face. In this a head of good clay may be moulded, and therein the eyes are to be opened, and other necessary amendments made. This second face being anointed with oil, a second mould of calcined alabaster is made, consisting of two parts joined lengthways along the ridge of the nose; and herein may be cast, with the same matter, a face extremely like the original.

If finely powdered alabaster, or plaster of Paris, be put into a basin over a fire, it will, when hot, assume the appearance of a fluid, by rolling in waves, yielding to the touch, steaming, &c., all which properties it again loses on the departure of the heat; and being thrown upon paper, will not at all wet it, but immediately discover itself to be as motionless as before it was set over the fire; whereby it appears, that a heap of such little bodies as are neither

spherical, nor otherwise regularly shaped, nor small enough to be below the discernment of the eye, may, without fusion, be made fluid, barely by a sufficiently strong and various agitation of the particles which compose it; and, moreover, lose its fluidity immediately upon the cessation thereof.

Two or three spoonfuls of burnt alabaster, mixed up thin with water, in a short time coagulate, at the bottom of a vessel full of water, into a hard lump, notwithstanding the water that surrounded it. Artificers observe, that the coagulating property of burnt alabaster will be very much impaired or lost, if the powder be kept too long, especially if in the open air, before it is made use of; and when it hath been once tempered with water, and suffered to grow hard, they cannot, by any burning or powdering of it again, make it serviceable for their purpose as before. Boyle's Works Abr. vol. i. p. 133. 313. 341.

This matter, when wrought into vessels, &c. is still of so loose and spongy a texture, that the air has easy passage through it. Mr. Boyle gives an account, among his experiments with the air-pump, of his preparing a tube of this plaster, closed at one end and open at the other, and on applying the open end to the cement, as is usually done with the receivers, it was found utterly impossible to exhaust all the air out of it; for fresh air from without pressed in as fast as the other, or internal air, was exhausted, though the sides of the tube were of a considerable thickness. A tube of iron was then put on the engine; so that being filled with water, the tube of plaster of Paris was covered with it; and on using the pump, it was immediately seen, that the water passed through into it as easily as the air had done, when that was the ambient fluid. After this, trying it with Venice turpentine instead of water, the thing succeeded very well; and the tube might be perfectly exhausted, and would remain in that state several hours. After this, on pouring some hot oil upon the turpentine, the case was much altered; for the turpentine melting with this, that became a thinner fluid, and in this state capable of passing like water into the pores of the plaster. On taking away the tube after this, it was remarkable that the turpentine, which had pervaded and filled its pores, rendered it transparent, in the manner that water gives transparency to that singular stone called *oculus mundi*. In this manner, the weight of air, under proper management, will be capable of making several sorts of glues penetrate plaster of Paris; and not only this but baked earth, wood, and all other bodies porous enough to admit water on this occasion. Phil. Trans. N° 122.

Plaster of Paris, diluted with water into the consistence of a soft or thin paste, quickly sets or grows firm, and at the instant of its setting, has its bulk increased; for Mr. Boyle has found, that a glass vessel, filled with the fluid mixture, and closely stopped, bursts while the mixture sets, and sometimes a quantity of water issues through the cracks.

This expansion of the plaster, in passing from a soft to a firm state, is one of its valuable properties; rendering it an excellent matter for filling cavities in sundry works, where other earthy mixtures would shrink and leave vacuities, or entirely separate from the adjoining parts.

It is probable also, that this expansion of the plaster might be made to contribute not a little to the elegance of the impressions which it receives from medals, &c. by properly confining the soft matter, that its expansion may force it into the minutest traces of the figure; the expansion of the matter doing the same office as the pressure by which the wax is forced into the cavities of a seal.

Plaster of Paris promotes the fusion of forged iron.

This substance is commonly used for taking casts and impressions from figures, busts, medals, &c. as it is adapted to the double use of making both casts and moulds for forming them. See *Impressions of MEDALS*.

PLASTER of Paris, in *Agriculture*, a substance of the calcareous kind, in combination with the vitriolic acid, which has been sometimes made use of as a manure. See GYPSUM and *Sulphate of LIME*.

PLASTER, in *Gunnery*, a piece of greased leather or rag, used by riflemen, &c. to make the ball fit the bore of the piece.

PLASTER Floors, in *Rural Economy*, such floors as are constituted of platter, prepared from such lime as possesses a strong binding property. They are highly useful in cottages and farm-houses, as affording much security against fire. In constructing them, it is observed, in the first volume of *Communications to the Board*, that the joists are laid in the usual manner; after which a sort of strong reed, which is found in Huntingdonshire, is nailed on, upon which the plaster is applied; but in order to save it, there is frequently a thin coat of common lime laid on first, to fill up the crevices and inequalities. On this the plaster is then spread out, to the thickness of about two inches, being laid on with as much expedition as possible. The plaster is sold at the kilns in the midland districts, at 6*d.* the bushel: and the expence of laying it on, if burnt and prepared, is 5*d.* the square yard; but if to be burnt and prepared by the workmen, about as much more. The floors are said to be excellent and cheap. Where reeds cannot be procured, laths may be made use of, but they come much higher. Floors of this sort are much in use in Nottinghamshire, as well as in Rutlandshire, at the earl of Winchelsea's, where the upper floors of his farm-houses are made of it.

These kinds of floors should be more attended to, in constructing small houses both of the cottage and other kinds, as being cheap, readily laid, and at the same time secure.

PLASTERING, in *Architecture*, is that operation which consists in laying on coats of mortar, variously prepared, on the ceilings and walls, &c. of different buildings. This belongs to a class of artificers called plasterers. See PLASTER.

Plasterers' work is of two kinds: namely, ceiling, which is plastering upon laths; and rendering, which is plastering upon walls. These are measured separately. The contents are estimated either by the foot, or yard, or square of 100 feet. Enriched mouldings, &c. are rated by running or

lineal measure. Deductions are to be made for chimnies, doors, windows, &c. But the windows are seldom deducted, as the plastered returns at the top and sides are allowed to compensate for the window opening.

It were much to be wished that this art of plastering could be again brought to its ancient perfection. In our best buildings the plastered walls and ceilings crack and fly, and in a little time grow damp, or moulder to decay.

The Romans had an art of rendering their works of this kind much more firm and durable, and there is no reason to despair of reviving this art by proper trials.

The ancient plastering of these people preserved to this time, where it has not met with violent blows or injuries from accidents, is still found as firm and solid, as free from cracks or crevices, and as smooth and polished on the surface, as if made of marble. The bottoms and sides of the Roman aqueducts were made of this plastering, and endured many ages without hurt, unless by accidents: witness that whereof some yards are still to be found on the top of the Pont de Gard, near Nîmes, for the support of which that famous bridge was built to carry water to the said town. The roofs of houses, and the floors of rooms, at Venice are covered with a sort of plaster, made of later date, and yet strong enough to endure the sun and weather for several ages, without cracking or spoiling, and without much injury from people's feet.

The secret of preparing this Venetian plaster is not among us; but it would be worth while to try whether such a substance might not be made by boiling the powder of gypsum dry over the fire, for it will boil in the manner of water; and when this boiling or recalcining was over, the mixing with it resin, or pitch, or both together, with common sulphur, and the powder of sea-shells. If these were all mixed together, and the water added to it hot, and the matter all kept hot upon the fire till the instant of its being used, so that it might be laid on hot, it is possible this secret might be hit upon,

Wax and oil of turpentine may be also tried as additions; these being the common ingredients in such cements as we have accounts of as the firmest. Strong ale-wort is by some directed to be used, instead of water, to make mortar of limestone of a more than ordinary strength. It is possible, that the use of this tenacious liquor to the powdered ingredients of this proposed plaster, might greatly add to their solidity and firmness. Phil. Trans. N° 93. See STUCCO.

Plated manufacture

PLATED MANUFACTURE, in the *Arts*. From the valuable properties possessed by silver as a metal, it is much to be regretted that it is not sufficiently plentiful, so as to be used for the fabrication of such articles as are liable to corrosion; more especially such utensils as are employed for culinary purposes. This desirable object has given rise to the desideratum of covering some of the cheaper metals with silver, and this art has always been known by the name of plating.

The art of plating with silver appears to have been first applied to articles made of brass, after they were in other respects finished. It is known by the name of French plating, and was formerly much used for brass candlesticks. After the goods were polished, and perfectly free from grease, and indeed any other extraneous matter, the part to be plated was heated to a temperature something short of changing the colour of the metal. Leaf silver was now laid upon the part, and, while hot, was rubbed on with a hardened steel burnisher, perfectly dry and clean. By this means the silver adhered firmly to the brass, which, from the action of the burnisher, assumed a fine polish. There had much the appearance in colour and lustre of those of the present day. They possessed but little permanence, owing to the thinness of the covering. This art is scarcely now practised, from the introduction of the superior plan of plating upon ingots of copper, and forming the utensils out of the sheets and wire made from the ingots. This latter is at present carried on to an immense extent in Sheffield, and also at Birmingham, but on a lesser scale.

The inventor of this method of making plated articles was not aware of its great importance. He began by making it into snuff-boxes, and other trifling articles. It afterwards was extended to the manufactory of pints and tankards, and other articles, by a Mr. Hancock, who erected a mill near Sheffield for rolling the ingots. This mill is at present employed for this purpose by the son of the above gentleman.

The plated manufacture is divided into three departments, in each of which a distinct set of workmen is employed.

Those workmen employed in making vessels, such as are required to be raised by the hammer, are called braziers, probably from braziers being first employed in it.

The next are called candlestick makers, being exclusively employed in making all the varieties of these articles.

The next and last are called pierce-workers: these were originally employed in making articles with ornamental open work, such as bread-baskets, and trays of different kinds.

This open work was formed by piercing the substance with punches of different shapes, by means of a screw-press called a fly.

This species of work is now become obsolete, since the invention of plated wire. The articles in which pierce-work had been made, are now formed by the varied intersections of wires, which give great lightness and elegance, with less waste and more expedition. The workmen employed in this department are still called pierce-workers.

Previously to describing particularly the different branches of this art, we shall give the method of preparing the plated sheets and wire of which all the different articles are made.

The ingots on which the silver is laid are not pure copper, but an alloy, consisting of copper and brass; this gives it a degree of stiffness greater than that of copper, which renders it less liable to be deformed when in use.

Fig. 12. in *Pl. Plated Manufacture*, represents a section of the furnace used for melting the alloy for the purpose of casting. The crucibles are those made at Chelsea with black-lead. The ingot-moulds are of cast-iron, consisting of two pieces, fastened together by two rings, with wedges, the interior being of the shape of a parallelepipedon, about three inches broad, 1½ in thickness, and about eighteen or twenty long. The mouth-piece, into which the metal is poured, makes an angle with the length of the cavity; so that when the mould is placed on the ground, with the narrow side uppermost, and makes an angle with the horizon of about ten degrees, the mouth-piece points directly upwards. The inclination of the mould and the length of the mouth-piece are to give a certain head of liquid metal, which determines the impurities of less specific gravity than the metal to rise into the cavity of the mouth-piece, in order to insure the soundness of the ingot. If this were not attended to, the sheets rolled from such ingots would abound with seams and loose places. It is easy to see that a small hole in the ingot would be the source of a seam by extension, and a larger cavity would have the effect of making hollow places in the substance of the sheet, which frequently peel off with the silver after plating.

The proper heat of the metals, and the temperature of the mould when the metal is poured, are of great importance, as far as regards the soundness of the ingot. When the metal is too cold, and its liquidity of course imperfect, the impurities cannot freely ascend, which causes imperfection in its substance. The same effect may take place from the moulds being cold: this, with the great conducting power of the metal mould, rapidly robs the metal of its caloric, and lessens its liquidity. The proper heat for the moulds is something short of burning the fat with which they are greased on the interior surface. The presence of fat which contains hydrogen has a happy effect in preventing the surface being rough. Its presence is therefore essential, and hence the moulds should never be so hot as to destroy it. On the other hand, the metal should not be too hot, as in this case it remains longer in the liquid state than is proper: this has the effect of allowing the metal to assume a more complete crystalline arrangement than under ordinary circumstances. When an ingot under such circumstances is broken, the crystals are very distinct. The sheet rolled from an ingot so cast, will be found to exhibit on its surface very thin loose pieces, which peel off. This is frequently a source of great mischief to the manufacturer. After the pieces are plated

and rolled, this last inconvenience is frequently so great, as to render the whole sheet useless, except to work over again.

It will be remembered, from what we observed respecting the temperature of the ingot moulds, that the proper heat for the metal can only be acquired by practice. Men of some talent and observation should have the management of casting and plating. It is notorious, however, throughout the trade, that the men employed in this essential department are generally taken from the class of common labourers.

The best test for the proper degree of heat of the metal is its colour, and the appearance of liquidity. When it first fuses it appears stiff, and of the colour of the red cokes of the furnace: with a greater heat it becomes more liquid, and assumes a blueish colour. This latter is the proper state for pouring it into the mould. If the heat be greater, the zinc of the brads, and perhaps the copper itself, begins to burn. This arises from the metal's assuming the form of vapour, which combines with the oxygen of the atmosphere. When the metal has become solid in the mould, the wedges which keep the two halves of the mould together are slackened, to prevent the ingot from breaking, by its contraction, during cooling. When it is taken from the mould its surface ought to be smooth and metallic. Its fracture should exhibit a rough uniform crystallization, in which the crystals present small surfaces. If the crystals appear distinct, with large faces, the metal will be shelly when rolled.

For the ordinary kind of work these ingots are generally cut in two in the middle, being more convenient for plating than longer pieces.

The next process is to dress the face of the ingot for the purpose of receiving the silver, on one or both sides, as it may be intended to be single or double plated. This is effected by filing, which is continued till the surface becomes entirely free from the least blemish. This is so important, that the naked eye should not be depended upon. A very small hole in the ingot would become a surface on rolling, and the silver would come off in that part. The surface of the copper should, therefore, be minutely examined by a magnifier before the silver is laid on. The thickness of the silver to be laid on the copper will be best known, when it is understood, that the silver, in single plated metal, or that plated on one side only, is from 8 to 10 pennyweights to the pound troy of copper; and, of course, double that quantity when plated on both sides. If the ingot of copper be $1\frac{1}{4}$ thick, the silver plate to be laid upon it, at eight pennyweights to the pound, will be $\frac{3}{4}$ of an inch, and a square inch of it will weigh about 90 grains. When the plate of silver is cut to a little less than the size of the copper surface, made flat, and scraped perfectly clean, the copper surface being equally clean, they are laid together, and the silver plate is tied down with wire. A little of a saturated solution of borax is now insinuated under the edge of the silver plate on every side: this fuses at a low red heat, and prevents the oxygen of the atmosphere from affecting the surface of the copper, which would prevent the adherence of the silver. In this state the ingot is brought to the plating furnace.

In *fig. 12*. B is an iron door, with a small hole to look through. This furnace has a grate on a level with the bottom of the door. The fuel consists of cokes. The ingot is laid upon the bare cokes, and the door shut. When it has acquired nearly a proper degree of heat, the plater applies to the hole in the door to observe the proper point, when the process is finished. When the silver and copper are uniting, the surface of the former begins to be

riveted, and this is the sign to remove the ingot from the fire as quick as possible. If it were allowed to stop longer, the silver would become alloyed with the copper, and completely spoiled.

In this process, the silver is, in fact, soldered to the copper, although no solder is expressly employed. It is well known to chemists, that an alloy of silver and copper, as well as many other alloys, is more fusible than either of the simple metals. From what takes place in the above process, it will be easily inferred, that a portion of silver and copper unite at contiguous surfaces, which fusing before the silver or the copper, unite the silver with the copper. The ingot, being now plated, is made perfectly clean, and is ready to be rolled. The first rollers employed for plated metal are of cast-iron, similar in size and construction to those employed for sheet iron and sheet copper. (See *ROLLING MILL*.) The metal is rolled cold, and annealed from time to time. When it has gone through the rollers a certain number of times, it acquires a certain degree of hardness, so that the rollers have not much effect upon it; and if the rolling were continued, the metal would crack. To remedy this evil, the metal is taken to a reverberatory furnace. It is laid upon a hearth of brick or fire-stone, and the flame of coal made to pass over it. The heat, however, is not intense, since the metal is required to be slowly heated to a dull red. It may now be cooled in the quickest way possible to save time, as quenching in water does not affect it, as is the case with steel. It now passes through the rollers, as before, till it becomes hard, and then annealed and rolled again, till it is reduced something short of the size required. This being done, it is again annealed and passed through a pair of rollers faced with cast steel, and finely polished. This gives the surface great smoothness and truth. It is now annealed for the last time: after this, the sheets are immersed in hot dilute sulphuric acid, then scoured with fine Calais sand, which fits them for the workmen to shape into different articles.

Having described the method of preparing the sheet plated metal, we shall next give an account of the method employed for manufacturing plated wire. This is generally a distinct business, being unconnected with the business of making the plated goods.

The pieces of metal to be plated for the purpose of making wire, are forged out of bar copper unalloyed. These pieces are of a cylindrical shape, and about 18 or 20 inches long, and about $1\frac{1}{4}$ inch in diameter. The true cylindrical shape is given to the copper by wire-drawing: it is then made perfectly clean and metallic by scraping. The silver to be laid upon it is much thinner in proportion to the copper than was stated in the sheet metal. The silver is first formed into a tube, one edge projecting a little over the other. A copper cylinder, a little less in diameter than the tube, and so much longer as to admit one end of it being fastened into a hole, is now heated red-hot, and fastened by one end in the hole. The tube is now slipped upon it, with the seam upwards. A flat steel burnisher, with rounded polished edges, and a handle at each end, is now rubbed briskly backward and forward upon the overlapped edges of silver, at the same time using considerable pressure. By this means the two surfaces are completely welded together, so that it would be difficult to find where the union had taken place.

The cylinder of copper intended to be plated, is now made perfectly clean, the inside of the silver tube being the same. It is now put upon the cylinder, which is about

two inches longer than the tube; a small groove is made round the cylinder coinciding with the ends of the silver tube. Into this groove the ends of the tube are closely worked, so as to render the space between the tube and the cylinder perfectly air-tight. The necessity of this will be obvious, since the whole is required to be heated red-hot, which would cause the oxydation of the copper, and prevent the silver from adhering to it. When the cylinder and tube are together heated slightly red-hot, the same burnisher that was used to unite the tube is now rubbed briskly over the tube in a longitudinal direction. This unites the silver firmly to the copper, and makes it fit for drawing into wire of various forms and sizes. The machinery employed for drawing this wire is precisely similar to that employed for brass and copper wire. The great variety of figure and form given to it depends upon the plate through which it is drawn. Some are flat, others half round, some fluted, or with mouldings. It is chiefly used for making bread-baskets, toast-racks, snuffers, and many other articles, affording much neatness and elegance, with little manual labour. The wire after drawing, like sheets after rolling, is annealed, and afterwards cleaned with hot dilute sulphuric acid.

We shall first describe the manufacture of sheet metal into various articles. It may be easily conceived, that the nature of this metal is so similar to copper, that the working of it with the hammer into various forms will be very similar to that used by copper-smiths, with the difference of more exact and complete tools, and greater care on account of the value of the metal. Formerly all the different shaped vessels were made with the hammer, which made the price of labour very great. Now, all vessels of simple form, and not of large size, are formed in dies by means of the stamping hammer. This operation is now so general, that some manufacturers employ as many as six or eight of these engines.

Figs. 1 and 2 are two views of the stamp. *A* is a large stone, the larger the better; *b*, the anvil on which the die, *c*, is secured by four screws. See ground plan.

In *fig. 1*, *a, a*, are two upright square pillars, with the angles opposed to each other, which work in angular recesses in the hammer *d*. This admits the hammer to slide freely and truly from top to bottom, by pulling at the rope *f*, which passes over the pulley *e*. This hammer is let fall from different heights, according to the effect to be produced.

All vessels may be raised by the stamp, with the exception of such as are immoderately large, or those of inordinate depth, compared with the diameter. Vessels which are of less diameter at the top and bottom than in the middle, must either be stamped on two pieces, or raised with the hammer by hand.

The dies are, or ought to be, made of cast steel, but it should be as hard as to weld to iron, so that the iron should not be much below the surface of the die. This precaution is necessary only when the die requires to be hardened. In other respects the whole may be cast steel. Those unhardened should be of harder cast steel. No other steel can answer, as it would be liable to abound with flaws, and would not be uniformly hard.

When the die is placed upon the anvil, and the metal cut into pieces of proper size, the next thing is to surround the top of the die with a paste made with oil and clay, an inch or two above the surface. This cavity is now filled with melted lead. The under side of the stamping hammer has a flat face of iron fitted into it, about the breadth and length of the die: this is called the *lickerup*. When the

lead becomes solid, the hammer is raised to a certain height and let fall upon it. The under side of the *lickerup*, from being cut on the surface into teeth in shape like those of a rasp, firmly adheres to the lead, which afterwards rises with the hammer. The metal is now placed over the die, and the hammer with its lead made to fall upon it, till the impression on the metal is complete. If the vessel to be stamped be of any considerable depth, two or three dies are often used, one bigger than another, the last being of the proper size and shape. It sometimes happens, that when the vessel has a long conical neck, they are obliged to have recourse to an auxiliary operation called drafting. These in the plate are called embossing punches.

In *fig. 11*, the punches are made of cast steel, and the cavities turned out in a lathe. The pieces *a, b*, are of lead. This operation is performed by a series of these punches of different sizes, beginning with the largest first, and gradually going on to the smallest. By this means a hollow cone may be raised out of a flat plate, three or four inches in length, and not more than an inch in diameter at the widest part. These punches are also employed for small articles of too great delicacy for the stamp.

It frequently happens, that one part of an article is made by the stamp, and the rest by the hammer. Sometimes they are rudely formed by the hammer and finished by the die.

Cylindrical and conical vessels are mostly formed by bending and foldering. The bending is performed on blocks of wood with wooden hammers, to avoid injuring the plated surface. We shall here recommend a method of turning rings, or any thing in a cylindrical or conical shape. It is already used to great advantage by tin-plate workers. This is done by a machine consisting of three rollers, a section of which is shewn in *figs. 5 and 6*. *A, B, C*, are the three rollers, and *a b e d* the piece of metal passed through them to receive the cylindrical or conical shape.

The upper roller, *A*, can be raised or lowered at pleasure, which has the effect of determining the diameter of the cylinder. When one end of the upper roller is higher than the other, it gives the conical shape. In order to folder the cylinder or cone, the two edges are made very true, and are kept in contact by binding with small iron wire. The part where the folder is intended to be run must be made perfectly clean by scraping. The folder employed is that called silver folder. It is an alloy of brass and silver, or rather an alloy of silver, zinc, and copper. The alloy of copper and silver is more fusible than either of these metals, and may be employed as a folder for silver, copper, or plated metal, when the plated metal has no zinc in its composition. It is, however, necessary to employ an alloy of brass and silver as a folder for plated metal. The brass should be the least possible, being no more than what is necessary to give the requisite fusibility to the folder, since too much brass would not only injure the colour, but its malleability is impaired, and the seam would break when it came to be hammered.

The folder is first cast into an ingot, and then rolled thin enough to cut with shears into small shreds. Besides the folder they also employ borax, and a substance which floats on the top of melted glass, and is taken off as refuse. It is called *sandiver*, and probably consists of sulphat of potash and flint. The borax is first calcined, which consists in driving off the water of crystallization. The white powder is then mixed with a little water, a small quantity of the powdered *sandiver* being at the same time added. After the team to be foldered has been smeared with this pulpy mass, and the bits of folder laid on, the whole is exposed to the heat of a lamp with a blowpipe; or if the substance be large, to a charcoal fire, urged with bellows. The borax first

fuses, and defends the parts to be united from the action of the air. The heat is then increased rapidly till the solder melts. The use of the sandiver is to prevent the iron wire from being soldered to the other metal. It appears that the salt in this substance is decomposed by the iron, by which the surface of the lathe becomes oxydated, and prevented from uniting with the silver or the copper. The sandiver has no action upon the other metals, and therefore does not prevent their union. When the united part is made clean, and hammered with polished tools, the seam cannot be seen on the silvered side. If a yellow line appear, the solder contains too much brass.

Vessels intended to have other forms are generally soldered up in a conical or a cylindrical form, according as the width at the top and bottom of the vessel varies. The metal is so malleable, even in the soldered part, that a skilful workman can give almost any form to a vessel with the hammer.

Mouldings are sometimes formed upon the edges of vessels, which serve to give much strength and stiffness, as well as being ornamental. This operation is performed by an instrument called a swage, see *figs. 3 and 4*. The part *A* lifts up by a joint, and the metal to be swaged is placed between the dies, as shewn in the figures: the part *b* is held in a vice, while the other rests upon it. By striking on the part *A*, at the same time shifting the metal forward, the bead is formed. In *fig. 3*, the part *a* is a guide to regulate the distance of the bead from the edge. The same effect is produced in a neater and more expeditious manner by the rollers, *figs. 8, 9*. *Fig. 10* is a section, shewing the form of the bead. The two wheels *a, a*, (*fig. 8*.) are placed upon an axis, which have pinions for the purpose, the lower one giving motion to the upper one. The groove in the upper wheel corresponds with the bead in the lower one, and the metal passed between assumes the same figure. This machine, a little varied, may be used as shears to cut the metal into pieces of uniform breadth. A part of the upper wheel *a*, for this purpose must be a little larger, and the edges square and sharp. The lower wheel being put on first, the other must be put on to the other axis, till the face of the enlarged part comes up to that of the other wheel, and in this situation secured by nuts. It will be evident, that if a piece of metal be now placed between them, that the metal will be cut by the projecting part of the upper wheel, in a similar manner to that employed for slitting iron.

The beading and moulding, however, is not at present much used. When prominent parts like these are merely plated metal, they, from being more exposed, soon become bare, and the copper surface is presented.

The greatest improvement ever made in this branch of manufacture, is the introduction of silver edges, beads, and mouldings. Without this means of defending the prominent parts which become so soon bare in the old method, the trade must long since have gone into disgrace, and ultimately to decay. The silver intended to form the prominent and ornamental parts is rolled extremely thin, a superficial inch sometimes not weighing more than 10 or 12 grains.

This is too delicate to have the ornamental form given to it by the swage above described. The two opposite dies being steel, if not very accurately made, would tear silver so delicate as that used for ornaments. It is necessary, therefore, that the sunk part of the die should be steel, and the opposite side lead, as was observed in the stamping, and this is the method generally employed to form these silver ornaments. It seems wonderful, that manufacturers have not thought of doing this by small rollers. It would only require to have the part in which the die is sunk

a wire ring of cast steel, the concave part being a little conical, and made to exactly correspond with a convex cone on one of a pair of rollers, so that by a little force it may be as firm as a solid roller. A ring of lead, or even a straight piece, might act opposite to the die. A much greater variety of dies might be made in this way, than by making dies flat. The dies would cost less, and be better executed. The silver would also run less risk of tearing, than by the stamp or the swage.

When these silver mouldings are formed, and the refuse metal poured off, they are laid upon a level plate, with the hollow side upwards. Small bits of resin are put into the hollow parts, and soft solder melted in with a folding iron, the point of the same being applied into the groove to keep it in a state of fusion. This is continued till the cavity is quite full. To prevent the folder from accidentally adhering to the convex part, it is previously covered with a paint-like compound of lize and whitening. The same expedient is resorted to in all cases where soft solder is employed, or when it is applied to great heat. The soft folder is formed of equal parts of lead and tin. The former metal has so great an affinity for lead, as to require the greatest care to keep these metals separate when one of them is in a state of fusion.

The silver shells, thus filled with soft folder, will now admit of being bent into almost any form. After they are fitted accurately to the place they are to occupy, the part being first made clean and partially tinned, they only require to be secured by temporary fastenings, till the parts can be exposed to a degree of heat capable of melting the folder. This unites the ornament, without leaving any appearance of folder on the outside.

In forming substances which have a massive appearance, such as the feet of tea urns, the handles of vessels, and plated table spoons, no other metal is employed but the sheet. The mass is formed of two shells, which, when put together, form an apparent solid. Each of the concave parts is first filled with soft folder, they are then fitted accurately together, and heat applied till the mass fuses, so that the apparently massive article consists of a shell of plated metal filled with soft folder. Bulky ornaments, in the form of shells and flowers, are frequently put on in this way; some in silver. These have a similar massive appearance to, and strongly imitate, real plate.

All goods formed by hand with the hammer, require great labour in finishing. After hammering the vessel into the proper shape, the marks of the hammer appear like so many flat places. These are removed from the outside of the vessel to the inside, when the inside is concealed, as in tea urns. This is effected by covering either the anvil or the hammer with a piece of the stuff called everlasting. The roughness is transferred to that surface in contact with the everlasting. In hammering plated metal from time to time, it requires to be annealed by heating it red-hot: this discolours both the silver and the copper. These are cleaned by boiling in dilute sulphuric acid, and scouring with Calais sand. The sulphuric acid to the water is in very small proportion. If the silver begins to appear black by boiling, the acid is too much, and must be watered. When the vessels are finished in every respect by the maker, and the surface free from oxyd, it frequently happens that bits of rosin, used with soft folder, adhere to it. This is removed by boiling in a weak solution of pearl ashes. The same is also used for cleaning the surface of tinned copper.

The vessels are now ready for burnishing, a process which we shall soon describe.

Our instructions hitherto have particularly applied to braziers' work ; we shall next describe the candlestick-making.

In this branch of the business there is great variety. In the commencement of this trade the object was chiefly to imitate those made of silver, and it began with the prevailing taste of imitating the different orders of architecture. The numerous points and prominences thus introduced, were ill fitted for plated metal, as in a very little time their silver disappeared, which gave them the most shabby appearance possible. This obliged the manufacturers to make them more plain and simple, and it was not till the discovery of the silver edges, that candlesticks of plated metal began to gain respect in the world of luxury and fashion. The stems of candlesticks have been made square ; some with sharp, others with rounded corners ; others oval, but the greatest number with round stems, which appear to be the most consistent and the most permanent. Of these, the patent telescope candlestick has had the greatest run. This consists in the cylindrical part lengthening and shortening at pleasure, by one tube sliding into the other. In this case the tubes are drawn by machinery, similar to that used for drawing the tubes of telescopes. The feet of candlesticks, or the base, are generally made in a die by the stamp. The neck, which is sometimes small in one part, is also stamped. The dish part of the nozzle or socket is made in a die, and the tube part in the same way as the cylindrical pillar. These, for the sake of neatness and expedition, are generally drawn in the wire drawing machine, whether for sliding or not. Some of these tubes are fluted. The prominent moulding and beads are generally of silver. The different parts are foldered together, some parts with hard and others with soft folder. The branches of candlesticks are formed in two halves, like the tea urn feet, &c. In forming such articles as are made of wire, such as bread baskets, toast racks, and casters, the wire is bent into the given form with a wooden block and a mallet. When pieces require to be foldered together, the joinings must be accurately fitted, in order to prevent the copper from appearing. In these cases hard folder is employed. This branch of plated manufacture admits of extensive application. Wires are capable of great variety of positions. The work lately published by sir James Hall, seems to prove that Gothic architecture has originated in the fanciful forms of bended twigs. The perusal of this work could not fail to give important hints to an ingenious manufacturer of plated wire work.

Plated goods, particularly tea urns, and globular vessels for the same purpose, frequently require to be engraved ; but it is obvious that, from the extreme thinness of the plate, the graver would lay bare the copper ; and if the plate was so thick all over as to admit of engraving, the articles would be very expensive. Both these evils are obviated, by working an extra plate of silver on to the part to be engraved. This is done while the plate, of which the vessel is made, is in its flat form. The part where the engraving will fall is first scraped clean, and a plate of silver, of similar thickness to that employed for silver edges, is cut

to the same size, and also scraped clean. The plated sheet is then laid upon a hot anvil, and the plate of silver laid upon the place prepared. It is first rubbed slowly, but with great pressure, with a polished hammer previously heated, but not so as to affect the polish. The plate will begin to adhere, and it may then be slightly hammered ; ultimately it will adhere all over, and may now be hammered on a polished flake, till the whole surface becomes plane, and the piece of silver cannot be distinguished from the rest. This process is on the same principle as the plating of wire, and is similar to welding two pieces of iron together. It appears practicable that the surfaces of any malleable metals, when clean and heated to acquire a certain degree of softness, are capable of uniting. Most people are familiar with the union of two pieces of lead by pressure, even at the common temperature.

When the different plated goods come out of the hands of the workmen, the metal, although clean, is of a dull white colour, possessing no polish whatever.

This last finish is called burnishing, and is generally performed by females in a distinct set of apartments. The burnishing tools are generally made of blood-stone, and some of hardened steel finely polished. The latter are to burnish the minute parts which cannot be touched by the blood-stone, which are employed chiefly for the greater and interrupted parts.

The bits of blood-stone are let into little cases, made of sheet iron, and then finely polished.

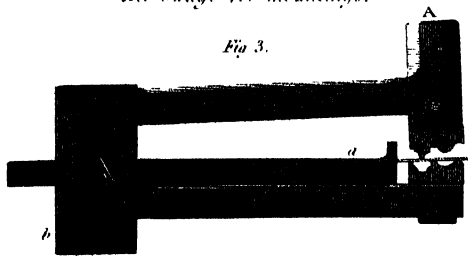
The burnishers, if used dry, would adhere to the silver in some places, and would scratch instead of giving the fine polish intended. This is obviated by frequently dipping the burnishing tool into a solution of white soap. After being burnished they are raised, and lastly wiped with clean sheep's leather.

It is a circumstance much to be regretted, that silver, although it is susceptible of so fine a polish, does not keep its lustre. This is occasioned by the sulphur which comes from sulphurated hydrogen, a gas always existing in the atmosphere. The thinnest coating of any substance will prevent this change. If the surface of silver were coated with a solution of gum arabic or isinglass, the defence will not be perceived, and the silver will never change colour.

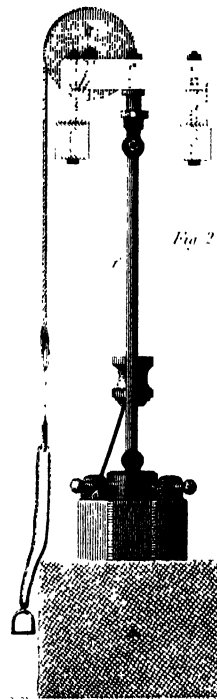
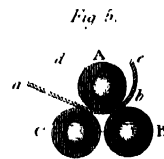
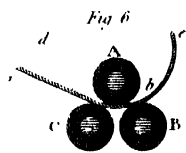
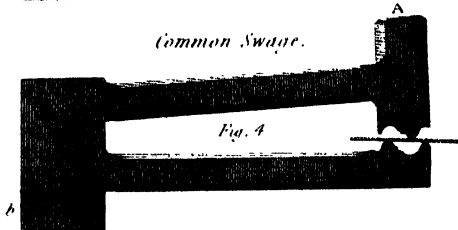
We shall conclude this article with a few remarks upon the present mode of plating the ingots intended for sheets. It will be evident, that since the heat in plating must be equal to forming a portion of an alloy of silver and copper, which by its early fusion unites the two surfaces together, the silver will not be uniform in its quality, and by wearing will present an alloy having more than its proper quantity of copper ; and will, in consequence, exhibit a base colour. It will be remembered, that the method used for plating the wire ingots does not admit of this inconvenience. The silver will keep its colour to the last. We shall no doubt hear, at some period when the plated manufacturers employ men of talent as platers, that the ingots for rolling will be plated by the method employed for the wire.

PLATED MANUFACTURE.

Bit Swage for mountings.



Common Swage.



Die Stamp

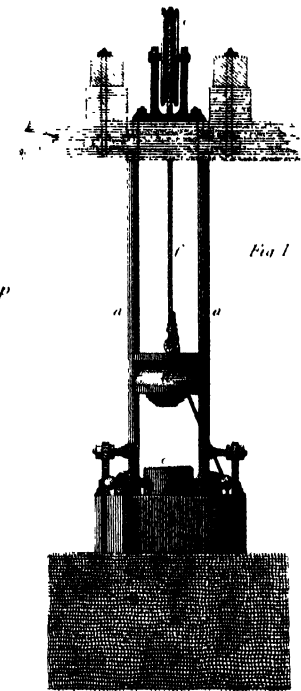
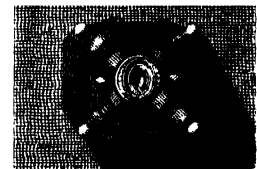
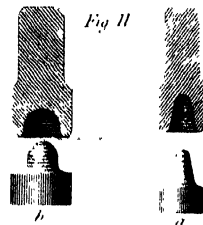


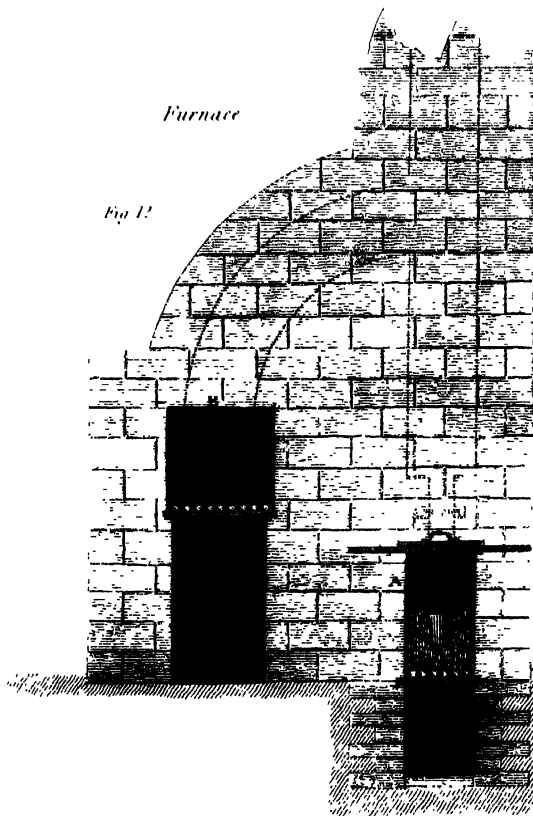
Fig 1

Embossing Punches



Furnace

Fig 12



grooved Rollers for beads &c

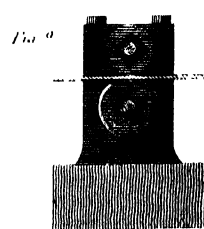


Fig 10

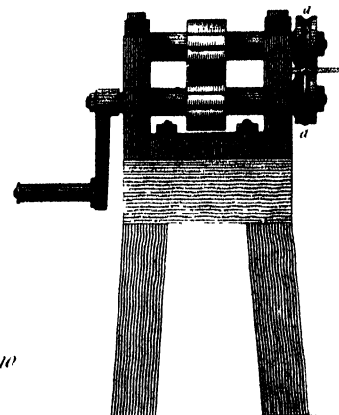


Fig 8

Plotting

PLOTTING, among *Surveyors*, the art of describing or laying down on paper, &c. the several angles and lines of a tract of ground surveyed by a theodolite, or the like instrument, and a chain.

In surveying with the plain-table, the plotting is needless; the several angles and distances being laid down on the spot as fast as they are taken.

But in working with the theodolite, femicircle, or circumferentor, the angles are taken in degrees; and the distances in chains and links. So that there remains a subsequent operation, to reduce those numbers into lines; and so to form a draught, plan, or map. The operation is called *plotting*.

Plotting, then, is performed by means of two instruments, the protractor and plotting-scale. By the first, the several angles observed in the field with a theodolite, or the like, and entered down in degrees in the field-book, are protracted on paper in their just quantity.

By the latter, the several distances measured with the chain, and entered down, in like manner, in the field-book, are laid down in their just proportion.

Under the articles **PROTRACTOR** and **PLOTTING-scale**, is found, severally, the use of those respective instruments in the laying down of angles and distances; we shall here give their use conjointly, in the plotting of a field, surveyed either with the circumferentor, or theodolite.

PLOTTING, Method of, from the circumferentor. Suppose an inclosure, *e. gr.* A B C D E F G H K (*Plate VI. Surveying, fig. 10.*) to have been surveyed: and the several angles, as taken by a circumferentor in going round the field, and the distances, as measured by a chain, to be found entered in the field-book, as in the following table.

	Deg.	Min.	Cha.	Link.
A	191	00	10	75
B	297	00	6	83
C	216	30	7	82
D	325	00	6	96
E	12	24	9	71
F	324	30	7	54
G	98	30	7	54
H	71	00	7	78
K	161	30	8	22

1. On a paper of the proper dimensions, as L M N O (*Plate VI. Surveying, fig. 11.*) draw a number of parallel and equidistant lines, representing meridians, expressed in dotted lines. Their use is, to direct the position of the protractor; the diameter of which must always be laid either upon one of them, or parallel thereto; the femicircular limb downwards for angles greater than 180° , and upwards for those less than 180° .

The paper being thus prepared, assume a point on some meridian, as A, whereon lay the centre of the protractor, and the diameter along the line. Consult the field-book for the first angle, *i. e.* for the degree cut by the needle at A, which the table gives you 191° .

Now since 191° is more than a femicircle or 180° , the femicircle of the protractor is to be laid downwards; where, keeping it to the point with the protracting pin, make a mark against 191° ; through which mark, from A, draw an indefinite line A b.

The first angle thus protracted, again consult the book for the length of the first line A B. This you find ten chains 75 links. From a convenient scale therefore, on the plotting-scale, take the extent of 10 chains 75 links be-

tween the compasses; and letting one point in A, mark where the other falls in the line A b, which suppose in B: draw, therefore, the full line A B for the first side of the inclosure.

Proceed then to the second angle; and laying the centre of the protractor on the point B, with the diameter as before directed, make a mark, as c, against 297° , the degrees cut at B; and draw the indefinite line B c. On this line, from the plotting-scale, as before, set off the length of your second line, *viz.* 6 chains 83 links; which extending from B to the point C, draw the line B C for the second side.

Proceed now to the third angle or station: lay then the centre of the protractor, as before, on the point C; make a mark, as d, against the number of degrees, cut at C, *viz.* $216^\circ 30'$: draw the indefinite line C d, and thereon set off the third distance, *viz.* 7 chains 82 links; which terminating, *e. gr.* at D, draw the full line C D for the third side.

Proceed now to the fourth angle D: and, laying the centre of the protractor over the point D, against 325° , the degree cut by the needle, make a mark e; draw the occult line D e, and thereon set off the distance 6 chains 96 links; which terminating E, draw D E for the fourth line: and proceed to the fifth angle, *viz.* E.

Here the degrees, cut by the needle, being $12^\circ 24'$ (which is less than a femicircle), the centre of the protractor must be laid on the point E, and the diameter on the meridian, with the femicircular limb turned upwards. In this situation make a mark, as before, against the number of degrees, *viz.* $12^\circ 24'$, cut by the needle at E; draw the line E f, on which set off the fifth distance, *viz.* 9 chains 71 links; which extending from E to F, draw the line E F for the fifth side of the inclosure.

After the same manner proceed orderly to the angles F, G, H, and K; then placing the protractor, making marks against the respective degrees, drawing indefinite lines, and setting off the respective distances, as above, you will have the plot of the whole inclosure, A B C, &c. Such is the general method of plotting from this instrument; but it must be observed, that in this process, the stationary lines, *i. e.* the lines in which the circumferentor is placed to take the angles, and in which the chain is run to measure the distances, are, properly, the lines here plotted. When, therefore, in surveying, the stationary lines are at any distance from the fence or boundaries of the field, &c. off-sets are taken, *i. e.* the distance of the fence from the stationary line is measured at each station; and even at intermediate places, if there prove any considerable bends in the fence.

In plotting, therefore, the stationary lines being laid down, as above, the off-sets must be laid down from them; *i. e.* perpendiculars of the proper lengths must be let fall at the proper places from the stationary lines. The extremes of which perpendiculars, being connected by lines, give the plot desired.

If, instead of going round the field, the angles and distances have been all taken from one station, the process of plotting is obvious, from the example above; all here required, being to protract, after the manner already described, the several angles and distances, taken from the same stationary point in the field; from the same point or centre on the paper. The extremities of the lines thus determined, being then connected by lines, will give the plot required.

If the field has been surveyed from two stations, the sta-

PLOTTING

tionary lines are to be first plotted, as above; then the angles and distances taken from each to be laid down from each respectively.

PLOTTING, Method of, where the angles are taken by the theodolite, i. e. by back-sight and fore-sight (as it is called) is somewhat different. To prepare the angles for plotting, the quantity of each must first be found, by subtracting the degrees of the fore-sight and back-sight from each other: the remainder is then the angle to be protracted. The use of parallel lines is here excluded; and instead of laying the protractor constantly on, or parallel to meridians, its direction is varied at every angle. The practice is thus:

Suppose the former inclosure to have been surveyed with the theodolite, after the manner of back-sight and fore-sight; and suppose the quantity of each angle to be found by subtraction.

An indefinite line is drawn at random, as A K, (*fig. 11.*) and on this the measured distance, *e. gr.* 8 chains 22 links, is set off, as in the former example: if now the quantity of the angle A have been found 140° , the diameter of the protractor is to be laid on the line A K, with the centre over A; and against the number of degrees, *viz.* 140, a mark made, an indeterminate line drawn through it, and the distance of the line A B laid down from the scale upon it.

Thus we gain the point B; upon which laying the centre of the protractor, the diameter along the line A B, the angle B is protracted, by making a mark against its number of degrees, drawing an occult line, and setting off the distance B C, as before.

Then proceed to C, laying the diameter of the protractor on B C, the centre on C protracts the angle C, and draw the line C D: thus, proceeding orderly to all the angles and sides, you will have the plot of the whole inclosure A B C, &c. as before.

PLOTTING-Scale, a mathematical instrument usually of box-wood, sometimes of brass, ivory, or silver, and either a foot, or half a foot long, and about an inch and a half broad.

It is denominated from its use in plotting of grounds, &c.

On one side of the instrument (represented *Plate VI. Surveying, fig. 12.*) are seven several scales or lines, divided into equal parts. The first division of the first scale is subdivided into ten equal parts, to which is prefixed the number 10, signifying that ten of those subdivisions make an

inch; or that the divisions of that scale are decimals of inches.

The first division of the second scale is likewise subdivided into 10, to which is prefixed the number 16, denoting that sixteen of those subdivisions make an inch. The first division of the third scale is subdivided in like manner into 10, to which is prefixed the number 20. To that of the fourth scale is prefixed the number 24; to that of the fifth, 30; that of the sixth, 40; and that of the seventh, 48; denoting the number of subdivisions equal to an inch, in each, respectively.

The two last scales are broken off before the end, to give room for two lines of chords, marked by the letters C C.

On the back-side of the instrument is a diagonal scale, the first of whose divisions, which is an inch long; if the scale be a foot, and half an inch, if half a foot, is subdivided, diagonally, into 100 equal parts; and at the other end of the scale is another diagonal subdivision, of half the length of the former, into the same number of parts, *viz.* 100.

Next the scales, is a line divided into hundredth parts of a foot, numbered 10, 20, 30, &c. and a line of inches subdivided into tenths, marked 1, 2, 3, &c.

PLOTTING-Scale, Use of the. 1. *Any distance being measured by the chain, to lay it down on the paper.*—Suppose the distance to be 6 chains 50 links. Draw an indefinite line; set one foot of the compasses at figure 6 on the scale, *e. gr.* the scale of 20 in an inch, and extend the other to five of the subdivisions, for the 50 links: this distance being transferred to the line, will exhibit the 6 chains 50 links, required.

If it be desired to have 6 chains 50 links, take up more or less space, take them off from a greater or lesser scale, *i. e.* from a scale that has more or fewer divisions in an inch.

To find the chains and links contained in a right line, as that just drawn, according to any scale, e. gr. that of 20 in an inch. Take the length of the line in the compasses, and applying it to the given scale, you will find it extend from the number 6 of the great divisions to five of the small ones; hence the given line contains 6 chains 50 links.

PLOTTING-Table, in *Surveying*, is used for a plain table, as improved by Mr. Beighton, who has obviated a good many inconveniences attending the use of the common plain table. See *Phil. Trans. N^o 461. sect. 1.*

Plumbago

PLUMBAGO, a name evidently derived from *plumbum*, lead, but whether it alludes to any colouring quality in the plant, or to the hue of its foliage, critics are not agreed. The latter seems consistent with *P. europæa*, or Common Leadwort, whose leaves are of a very peculiar greyish-green. The *Polygonum Persicaria*, with dark spots on its leaves, has sometimes borne this name, for a similar reason.—Linn. Gen. 86. Schreb. 114. Willd. Sp. Pl. v. 1. 837. Mart. Mill. Dict. v. 3. Ait. Hort. Kew. v. 1. 323. Brown Prodr. Nov. Holl. v. 1. 425. Sm. Prodr. Fl. Græc. Sibth. v. 1. 131. Juss. 92. Tourn. t. 58. Lamarck Illustr. t. 105. Gærtn. t. 50.—Class and order, *Pentandria Monogynia*. Nat. Ord. undetermined by Linnæus. *Plumbagines*, Juss.

Gen. Ch. *Cal.* Perianth inferior, of one leaf, ovate-oblong, tubular, with five plaits or angles, and five teeth, rough, permanent. *Cor.* of one petal, funnel-shaped; tube

cylindrical, contracted upwards, longer than the calyx; limb in five ovate, rather spreading, segments. *Stam.* Filaments five, awl-shaped, unconnected with the corolla, enclosed within its tube; anthers small, oblong, versatile. *Pist.* Germen superior, ovate, very small; style simple, the length of the tube; stigmas five, slender, simple. *Peric.* Capsule ovate, thin, of one cell and five incomplete valves. *Seed* solitary, ovate.

Obs. We find no traces of the nectary, or valves supporting the stamens, described by Linnæus.

Ess. Ch. Corolla funnel-shaped. Stamens inserted into the receptacle. Stigmas five. Capsule membranous, of one cell. Seed solitary.

1. *P. europæa*. Common Lead-wort. Linn. Sp. Pl. 215. Sm. Fl. Græc. Sibth. t. 191, unpubl. (P. Plinii; Ger. Em. 1254. Tripolium Dioscoridis; Column. Ecphr.

160. t. 161.)—Leaves clasping the stem, lanceolate-oblong, rough. Stem straight, erect.—Native of the south of Europe. Perennial and hardy in our gardens, but not in general cultivation. The stem is herbaceous, three feet high, upright, leafy, furrowed, with many straight upright flowering branches, each terminating in a simple dense spike, of small pale-purple flowers with a bristly calyx. The leaves are alternate, numerous, recurved, oblong-lanceolate, obtuse, bluntly toothed, dull green, rough but not hairy; their base tapering, then dilated round the stem or branch.

2. *P. lapathifolia*. Dock-leaved Lead-wort. Willd. n. 2. (*P. orientalis*, *lapathi folio*, flore minore albedo; Tourn. Cor. 7.)—"Leaves clasping the stem, lanceolate, smooth. Stem divaricated."—Native of Iberia. Stem taller, with longer more spreading branches; leaves much larger, smooth; flowers about half the size of the foregoing. Willd.

3. *P. capensis*. Cape Lead-wort. Thunb. Prodr. 33. Willd. n. 3.—"Leaves stalked, oblong, nearly entire; glaucous beneath. Stem erect." Thunb.—Native of the Cape of Good Hope.

4. *P. zeylanica*. Ceylon Lead-wort. Linn. Sp. Pl. 215. Willd. n. 4. Ait. n. 2. Brown n. 1. (*Lychnis indica* spicata, *ocymastris foliis*, fructibus lappaceis oblongis, radice urente; Comm. Hort. v. 2. 169. t. 85.)—Leaves stalked, oblong-ovate, smooth, entire. Stem erect, round.—Native of the East Indies, and New Holland. It flowers in the stove from April to September. The stem is rather shrubby. Flowers white; with a long tube.

5. *P. rosea*. Rose-coloured Lead-wort. Linn. Sp. Pl. 215. Willd. n. 5. Ait. n. 3. Curt. Mag. t. 230. (*Radix vesicatoria*; Rumph. Amboin. v. 6. 453. t. 168.)—Leaves stalked, ovate, smooth, somewhat toothed. Joints of the stem tumid.—Native of the East Indies; said to have been introduced by Dr. Fothergill in 1777. It blooms in the stove almost all the year long; and is the most favourite species of its genus, on account of the delicate pale scarlet of its flowers, which form compound clusters at the ends of the branches. The stem is shrubby, four or five feet high, slender, and requiring support. Leaves recurved.

6. *P. scandens*. Climbing Lead-wort. Linn. Sp. Pl. 215. Willd. n. 6. Ait. n. 4. (*Dentellaria lychnioides* *sylvatica* *scandens*, flore albo; Sloane Jam. v. 1. 211. t. 133. f. 1.)—Leaves stalked, ovate, smooth. Stem zigzag, climbing. Native of the West Indies. It was brought into the stoves of this country very early, but is not much regarded at present, the flowers being white and not striking in their appearance. Sloane compares them to the common field Campion. The climbing, much more lofty stem, distinguishes it from the two last. Their leaves are variable, and afford no well-marked distinction.

7. *P. auriculata*. Auricled Lead-wort. Lamarck Dict. v. 2. 270. Willd. n. 7.—Leaves stalked, ovate-oblong, with scaly dots beneath. Footstalks auricled at their base, and clasping the stem.—Native of the East Indies. Stem shrubby, slender. Leaves obtuse, smooth above; contracted at their base. Flowers in short terminal spikes, resembling those of *P. rosea* in form, but in the dried specimen they had no appearance of a red colour. Lamarck.

8. *P. triflora*. Dark-flowered Lead-wort. Ait. n. 5.—"Leaves obovate, abrupt, smooth.—Native of the Cape of Good Hope, from whence it was sent to Kew by Mr. Masson, in 1792. This is a greenhouse shrub, flowering in May and June. We have seen no specimens of these two last species.

PLUMBAGO, in Gardening, contains plants of the herbaceous, flowering, perennial kinds, of which the species cultivated are; the European leadwort (*P. europæa*); the

Ceylon leadwort (*P. zeylanica*); the rose-coloured leadwort (*P. rosea*); and the climbing leadwort (*P. scandens*).

Method of Culture.—The first sort is increased by parting the roots in the autumn, when the stems decay, and planting them in a dry soil. They should afterwards be kept clear from weeds, and have proper support.

The three other sorts should be raised from seeds, which should be sown in pots in the spring, and plunged in hot-beds. They likewise may sometimes be raised by planting slips and cuttings in pots, and plunging them in the same sorts of hot-beds.

These are all ornamental flowering plants; the first in the pleasure-grounds, and the others in pots among hot-house collections.

PLUMBAGO, in Metallurgy, a metalline recement, separated in the purification of gold or silver with lead, and sticking to the sides of the furnace.

This is otherwise called *molybdæna*; and has the same virtue with litharge. See MOLYBDÆNA.

PLUMBAGO seems to have been used, among the Ancients, for Black LEAD (which see), and employed in making pencils for designing, &c.

The black lead used for this purpose, called "plumbago," and also "carbure of iron," by Werner "graphit," the "fer carbure" of Haüy, is a species of coal, or mineral carbon (see COAL), of a dark iron black colour, passing into steel-grey, and occurs in mass, in kidney-shaped lumps, and disseminated. It has a glistening metallic lustre; its fracture is small, somewhat curved foliated, approaching to scaly, or granular uneven: in the great it is flaty. It occurs generally in granular or scaly distinct concretions; takes a polish by cutting or rubbing; gives a dark lead-grey streak, and is unctuous to the feel, soft, and not very brittle. Spec. grav. 1.98 to 2.26. It does not flame when heated, nor can by itself to support combustion. After long exposure to a high heat in a muffle, its carbon is burnt off, and its earthy and metallic part remains behind. If one part of plumbago, and two of very caustic dry alkaline, be heated in a retort with the pneumatocchemical apparatus, the alkaline becomes effervescent, hydrogenous gas is obtained, and the plumbago disappears. This experiment proves, that the small quantity of water contained in the salt is decomposed, and that its oxygen, by combining with the carbon of plumbago, forms the carbonic acid. The sulphuric acid does not act upon plumbago, according to Scheele. Pelletier has observed, that 100 grains of plumbago, and four ounces of oil of vitriol, being digested in the cold for several months, the acid acquired a green colour, and the property of congealing by a very slight degree of cold. The sulphuric acid distilled from plumbago passes to the state of the sulphureous acid; at the same time that carbonic acid is obtained, and an oxyd of iron is left in the retort. The nitric acid has no action upon plumbago, unless it be impure. The muriatic acid dissolves the iron and clay which contaminate native plumbago. Messrs. Berthollet and Scheele availed themselves of this method to purify it. The liquor being decanted after digestion upon the plumbago, the residue is then washed and submitted to distillation to separate the sulphur. The muriatic acid alone has no action upon plumbago, but the oxygenated muriatic acid dissolves it; the result being a true combustion effected by the oxygen of the acid, and the carbon of the plumbago. If ten parts of the nitrate of pot-ash be fused in a crucible, and one part of plumbago be thrown upon it by a little at a time, the salt will deflagrate, and the plumbago will be destroyed. The matter which remains in the crucible consists of very effervescent

alkali, and a small portion of martial ochre. If plumbago be distilled with muriat of ammonia, the muriate sublimes, coloured by the iron. All these facts prove that plumbago is a peculiar combustible substance, a true charcoal combined with a martial basis. The purer kind of plumbago, according to Scheele and Berthollet, consists of about 90 *per cent.* of carbon and 10 of iron. An impure kind from Pluffier afforded Vauquelin

23 carbon
2 iron
37 alumine
38 silic

100

The brilliant charcoal of certain vegetable substances, more especially when formed by distillation in close vessels, possesses all the characters of plumbago : and the charcoal of animal substances, possesses characters still more peculiarly resembling it. When animal substances are distilled by a strong fire, a very fine powder sublimes, which attaches itself to the inner part of the neck of the retort. This substance may be made into excellent black-lead pencils. Carbon may be formed in the earth by the decomposition of wood, together with pyrites ; but the origin of plumbago, says M. Chaptal, is principally owing to the ligneous, and truly indecomposable, part of the wood, which resists the destructive action of water in its decomposition of vegetable substances. This mineral is found in primitive and transition rocks in England, Scotland, France, Spain, Germany, America, &c. Besides its use for pencils, the best for this purpose is that from Borrowdale, in Cumberland ; it is sometimes used to lubricate machinery instead of oil, and to protect iron from rust. The hearths and plates of chimnies and other utensils, which appear very bright, owe their colour to plumbago. For this purpose Homberg long ago, *viz.* in 1699, directed 8lbs. of hog's-lard to be melted with a small quantity of water, with the addition of 4 oz. of camphor. When this last is fused, the mixture is taken from the fire ; and while it is yet hot, a small quantity of plumbago is added to give it a leaden colour. When this is to be applied, the utensils must be heated to such a degree, that the hand can scarcely bear to touch them. In this state the composition must be rubbed on them, and afterwards wiped when the piece is dry. Those who prepare small shot, use black lead to polish or glaze it, by rolling or agitating them together with a quantity of plumbago. It is likewise used to make razor strops. When kneaded with clay, it makes excellent crucibles. One part of plumbago, three of argillaceous earth, and a small quantity of cow's dung very finely chopped, form an excellent lute for retorts ; this lute is very refractory ; and the glass will melt with the coverings changing its form. Aikin's Dict. Chaptal's Chem. vol. ii.

Pomet says, that plumbago was the sea-lead, *plumbum marinum*, of the ancients ; who, he notes, took black-lead for a production of the sea, not a mineral, as it really is ; but this is scarcely credible.

PLUMBAGO, in the *History of the Gems*, a word used by the Roman authors to express a blemish common to their worse kinds, and greatly debasing their value. It was a sort of blueish or blackish deadness in the stone, which mixed itself with the other colour, be that what it would, and rendered it dull and dead. The emerald was of all the gems the most subject to this fault ; and in this case, its fine green colour was always rendered cloudy and blueish ; and in some lights the stone appeared of a dusky greyish-blue,

with no green at all in it. The Bactrian emeralds, which were in great esteem with the ancients, were often subject to this imperfection ; and those of Cyprus, taken out of the copper mines, though subject to many other imperfections, were usually quite free from this.

PLUMBAGO, in *Mineralogy*, a name given by many authors to a sort of fossil, having very much the appearance of a lead-ore, but not such in reality.

It is called also galena, blende, and mock-lead. It is usually of a plated texture, and dark blackish-blue colour, like the lead-ores ; but on trial it yields no metal. See GALENA and BLENDE.

PLUMBARIA, in *Ancient Geography*, an island situated on the coast of Spain, near the promontory Dianium, according to Strabo.

PLUMBATÆ, among the *Ancients*, a kind of scourge, the thongs of which were armed with lead.

PLUMBATÆ likewise signified leaden balls, used by soldiers to annoy the enemy with ; whence the soldiers were called *martio-barbuli*.

PLUMBERY, formed of *plumbum*, lead, the art of casting, preparing, and working lead ; and of using it in buildings, &c. See LEAD.

The lead used in plumbery is furnished from the lead-works in large ingots, or blocks, called pigs of lead, ordinarily weighing about a hundred pounds a-piece.

As this metal melts very easily, it is easy to cast figures of it, of any kind, by running it into moulds of brass, clay, plaister, &c. But the chief article in plumbery is the sheets, and pipes of lead. They are these which make the basis of the plumber's work in building ; the process of these, therefore, we shall give a description of.

Method of casting large Sheets of Lead.—The lead destined for this use is melted in a large cauldron or furnace, usually built with free-stone and earth, fortified on the outside with a mass of shards and plaister. At the bottom of it is a place sunk lower than the rest, in which is disposed an iron pot, or pan, to receive what may remain of the metal after the sheet is run. The furnace is so raised above the area of the floor, as that the iron pot just rests on it.

To use the furnace, they heat it with wood laid within it ; that done, they throw in the lead at random with the burning coals, to melt.

Near the furnace is the table or mould, on which the lead is to be cast. This consists of large pieces of wood, well jointed, and bound with bars of iron at the ends. Around it runs a frame, consisting of a ledge or border of wood, two or three inches thick, and one or two high from the table, called the *sharps*. The ordinary width of the tables is from three to four feet ; and their length from eighteen to twenty feet.

This table is covered with fine sand, prepared by moistening it with a watering pot, then working it with a stick ; and at last, to render it smooth and even, beating it flat with a mallet, and planing it with a slip of brass, or wood.

Over the table is a strike or rake of wood, which bears and plays on the edges of the frame, by means of a notch cut in either end of it ; and is so placed, as that between it and the sand is a space proportionable to the intended thickness of the sheet. The use of this strike is to drive the matter, while yet liquid, to the extremity of the mould.

At top of the table is a triangular iron peel or shovel, bearing, before, on the edge of the table itself, and behind, on a tressel somewhat lower than the table. Its use is in conveying the metal into the mould ; and the design of its oblique disposition is, that it may by that means be able to retain the metal, and keep it from running off at the fore-side,

where it has no ledge. Some of these peels are big enough to hold fifteen or sixteen hundred weight of lead, and even more.

Things being thus disposed, with a large iron ladle they take out the melted lead, coals and all, out of the furnace; and with this, mixed as it is, they fill the iron peel. When full, they take out the coals, and clear the lead with another iron spoon, pierced after the manner of a scummer.

This done, they hoist up the lower part of the peel by its handle; upon which the liquid matter running off, and spreading itself on the mould, the plumber conducts and drives it to the extremity of the table, by means of the strike, which the workman passes along the ledges, and thus renders the sheet of an equal thickness.

The sheets thus cast, there remains nothing but to edge them, *i. e.* to planish the edges on both sides, in order to render them smooth and straight.

Method of casting thin Sheets of Lead.—The table or mould here used is of a length or breadth at discretion, only ledged on one side. Instead of sand, they cover it with a piece of woollen stuff, nailed down at the two ends, to keep it tight; and over this they lay a very fine linen cloth. The feet of the table are uneven, so that it does not stand horizontal, but moderately inclined.

Great regard is, in this process, had to the lead while melting, that it have the just degree of heat, so as it may run well, yet not burn the linen. This they judge of by a piece of paper; for if the paper take fire in the liquid lead, it is too hot; and if it be not shrunk and scorched a little, it is not hot enough.

Being then in its just degree, they have a strike, but different from that described in the former article; as serving both for peel and strike; both to contain and to conduct the liquid lead. It is, in effect, a wooden case without any bottom, only closed on three sides. It is pretty high behind, but the two sides, like two acute angles, still diminish to the tip, from the place where they are joined to the third or middle piece, where they are of the same height with it; *viz.* seven or eight inches high. The width of the middle makes that of the strike, which again makes that of the sheet to be cast.

The strike is placed at top of the table, which is before covered in that part, with a pasteboard, that serves as a bottom to the case, and prevents the linen from being burnt while the liquid is pouring in. The strike is so disposed on the table, as that the highest part looks to the lower end of the table, and the two sloping sides to the higher end.

The strike is now filled with lead, according to the quantity to be used; which done, two men, one at each side the table, let the strike descend down the table, or else draw it down with a velocity greater or less, as the sheet is to be more or less thick; the thickness of the sheet still depending on the promptitude with which the strike slides down the inclining mould.

The fine smooth sheets of lead, thus made, are sometimes used between the joints of large stones in great buildings, &c.

For the method of casting pipes, without soldering, see PIPE.

The folder which the plumbers use, is a mixture of two pounds of lead with one of tin. See SOLDER.

Plumber's work is commonly estimated by the pound or hundred weight; but the weight may be discovered by the measure of it, in the manner below stated. Sheet lead used in roofing, guttering, &c. is commonly between seven and twelve pounds weight to the square foot; but the following table shews by inspection the particular weight of a square foot for each of several thicknesses.

Thickness.	Pounds to a Square Foot.	Thickness.	Pounds to a Square Foot.
.10	5.899	.15	8.848
.11	6.489	.16	9.438
	6.554	$\frac{1}{2}$	9.831
	7.078	.17	10.028
	7.373	.18	10.618
.13	7.668	.19	11.207
.14	8.258	.2 = $\frac{1}{2}$	11.797
	8.427	.21	12.387

In this table the thickness is set down in tenths and hundredths, &c. of an inch; and the annexed corresponding numbers are the weights in avoirdupois pounds, and thousandth parts of a pound. So the weight of a square foot of $\frac{1}{10}$ or $\frac{1}{100}$ of an inch thick, is 5 pounds and 899 thousandth parts of a pound; and the weight of a square foot to $\frac{1}{2}$ of an inch thickness is 6 pounds and $\frac{1}{100}$ of a pound. Lead pipe of an inch bore is commonly 13 or 14 pounds to the yard in length.

Examples.

1. How much weighs the lead which is 39 feet 6 inches long, and 3 feet 3 inches broad, at $8\frac{1}{2}$ lbs. to the square foot?

Decimals.	Duodecimals.
39.5	39
$3\frac{3}{4}$	3
118.5	118 6
9.875	9 10 6
128.375	128 4 6
$8\frac{1}{2}$	$8\frac{1}{2}$
1027.000	1024
64.1875	64
1091.1875	2
	0.1

Answer 1091 $\frac{3}{4}$ lbs.

2. What cost the covering and guttering of a roof with lead, at 18s. the cwt.; the length of the roof being 43 feet, and the breadth or girth over it 32 feet, the guttering 57 feet long, and two feet wide; the former 9.831 lbs., and the latter, 7.373 lbs. to the square foot? Ans. 115l. 9s. 1 $\frac{1}{2}$ d. Hutton's Mensuration.

PLUMBING, among *Miners*, a term used to express the using a mine dial, in order to know the exact place of the work where to sink down an air shaft, or to bring an adit to the work, or to know which way the load inclines when any flexure happens in it.

It is performed in this manner: a skilful person with an assistant, and with pen, ink, and paper, and a long line and a sun-dial, after his guess of the place above ground, descends into the adit or work, and there fastens one end of the line to some fixed thing in it; then the incited needle is let to rest, and the exact point where it rests is marked with a pen: he then goes on farther in the line still fastened, and at the next flexure of the adit he makes a mark on the line by a knot or otherwise; and then letting down the dial again, he there likewise notes down that point at which the needle stands in this second position. In this manner he proceeds from turning to turnings, marking down the points,

and marking the line till he comes to the intended place this done, he ascends, and begins to work on the surface of the earth what he did in the adit, bringing the first knot in the line to such a place where the mark of the place of the needle will again answer its pointing, and continues this till he comes to the desired place above ground, which is certain to be perpendicularly over the part of the mine into which the air-shaft is to be sunk.

PLUMBUM. See LEAD.

PLUMBUM *Corneum*, called also *Saturnus corneus*, in *Chemistry*, is a metallic salt, formed by the precipitation of lead from its solution in nitrous acid with the marine acid, and all the neutral salts which contain it. It is thus called from its resemblance to the luna cornea. This salt may be made by other methods, and particularly by disengaging the volatile alkali from sal ammoniac by lead. In this way Mr. Margraaf makes the plumbum corneum, which he employs in the preparation of phosphorus. See LEAD.

Polisher

POLISHER, an instrument, called also a burnisher, used for polishing and burnishing gold, silver, and other metals, when gilt or silvered; and matters of other kinds, proper to take a polish.

The polisher is different in the different arts and manufactures. The gilders use an iron polisher, to prepare their metals before gilding; and the blood-stone, to give them the bright polish after gilding.

The polisher used by the makers of spurs, bits, &c. is part iron, part steel, and part wood. The instrument consists of an iron bar, with a wooden handle at one end, and a hook at the other, to fasten it to another piece of wood held in the vice, while the operator is at work. In the middle of the bow, within side, is what they properly call the polisher; which is a triangular piece of steel, with a tail, by which it is rivetted to the bow. What the cutlers call their polishers are a kind of wooden wheels, for grinding, made of walnut-tree, an inch thick, and of a diameter at pleasure. They are turned by the great wheel; and it is on these they polish and smooth their works with emery and putty.

The polishers used in the manufacture of glass are very different from all these. They consist of two pieces of wood; the one flat, covered with old hat; the other long and half round, fastened on the former, whose edge it exceeds, on both sides, by some inches: which serve the workman to take hold of, and to work it backwards and forwards by.

The polishers used by spectacle-makers are pieces of wood a foot long, seven or eight inches broad, and an inch and a half thick, covered with old castor hat, on which they polish the shell and horn frames their spectacle glasses are to be set in.

POLISHING, the art of giving a gloss or lustre to a thing; particularly a precious stone, marble, glass, a mirror, or the like.

For grinding and polishing steel, the grindstones that are used are made to revolve, either vertically or horizontally, with a velocity so great, as to describe sometimes as much as sixty feet in a second. The steel is also, in some cases, drawn backwards and forwards horizontally on a circular surface; and in order that the action may be equally distributed throughout the surface, it is allowed to revolve on an axis by means of the friction: its motion being confined to one direction by the action of a catch. Various substances, chiefly of mineral origin, are also used, on account of their hardness, as intermediate materials, for grinding and polishing others. These are diamond dust, corundum, emery, tripoli, putty, glass, sand, flint, red oxyd of iron, or crocus martis, and prepared chalk. These are sometimes applied in loose powder, and sometimes fixed on wood, leather, or paper. Cattle-fish bone and seal-skin are furnished by the animal kingdom; and Dutch rushes by the vegetable; these are employed chiefly in polishing wood or ivory. Marble is made smooth by rubbing one piece on another, with the interposition of sand; the polishing blocks are sometimes caused to revolve by machinery in a trough, in which the marble is placed under water, and are drawn at the same time gradually to and from the centre; or the

slab itself, with the frame on which it rests, is drawn slowly backwards and forwards, while the blocks are working in it. (See *Polishing of MARBLE*.) Granite is polished with iron rubbers, by means of sand, emery, and putty: but it is necessary to take care, during the operation, that the water, which trickles down from the rubbers, and carries with it some of the iron, may not collect below the columns, and stain them; an inconvenience which may be wholly avoided by employing rubbers of glass.

For the method of grinding and polishing optical lenses, see **GRINDING, LENS, and MIRROR**.

POLISHING of Glasses, Lenses, &c. succeeds the grinding of them.

The polishing of a mirror is the last preparation given it with emery or putty.

For an account of the methods recommended by various authors for polishing glass and metals in the construction of telescopes, &c. see **GRINDING**.

For the polishing of diamonds, &c. see **LAPIDARY**; see also **DIAMOND, and GEMS**.

When plates of glass for looking-glasses and mirrors are prepared in the manner stated under **LOOKING-Glasses and MIRROR**, the next process is that of polishing both surfaces to that perfect brightness which is observable in finished mirrors, so that the rays of light may pass through unimpaired to the silvering on the posterior surface, and be reflected again from thence, according to the laws of catoptrics. The substance used to give this last polish is colcothar, imported from this country, and called "rouge d'Angleterre," or "Potée." It is the residue left in the retorts of the aquafortis-makers, and when well washed and levigated consists of little else than a red and perfect oxyd of iron. The polishing instrument is a block of wood covered with several folds of black cloth with carded wool between each fold, so as to make a firm elastic cushion. This block has a handle for the workman to hold; for the whole of this part is done by hand and not by machinery, as the latter would work too uniformly, and not allow of that variation of pressure and those finishing touches which are required to bring every part of the glass to exactly the same height of polish. But to increase the pressure of the polisher, without fatiguing the workman, the handle is lengthened by a wooden spring bent to a bow, and three or four feet long, which at the other extremity rests against a fixed point in a beam placed above. The plate being fixed on the table by plaster, he then moistens the polisher with a wet brush, covers it with colcothar, and begins his operation by working it backwards and forwards over the surface of the plate. Much practical skill and dexterity is required to give an uniform and high degree of polish over the surface of a large plate, as it must be done by separate portions, and the finishing touches given with great care. The glasses of moderate size are completed in four portions from corner to corner, the centres of which intermingle so as to leave no part untouched, but the larger glasses require additional polishing in the centre. When one side is completed, and the reverse is about to be done, the polished side, now the undermost, is entirely covered with the red colcothar, to prevent the dazzle reflected from the white plaster, which

would prevent the workman from judging so accurately of the state of the surfaces on which he is employed. When both sides of the glass are thus brought to the same perfection of polish, the operation is finished by inspecting the glass, first cleaning both surfaces, and laying it, each side alternately upwards, upon a dark blue or black cloth, admitting only a moderate light, and if any part appear less highly finished than the rest it is retouched by a small hand-polisher and colcothar as before.

When a number of smaller pieces of glass, such as are used only for chamber or similar mirrors are to be polished, they are laid together on the table, and several of them polished at a time. But as these consist of pieces often of

unequal thicknets, though their surfaces have been rendered perfectly flat by the previous grinding, if they were simply placed side by side, and fixed on the table by plaster as usual, the polisher would not work well over such a variety of heights, and would act chiefly on the edges of each piece of plate. Therefore they are all first arranged on a large smooth plate, finished all but the polishing, and previously wetted, and plaster is poured upon them by which they are fixed together, and then when taken off, the surfaces which were in contact with the plate are perfectly level with each other, and the polishing goes on with the same ease as on an entire plate.

For an account of the next operation, which is that of *Silvering*, see that article, and *LOOKING-Glass*.

Porcelain

PORCELAIN, or **PURCELAIN**, a fine sort of earthenware, chiefly manufactured in China, and thence also called *china*, or *china-ware*; but brought into Europe from

other parts of the East, especially Japan, Siam, Surat, and Persia.

The Chinese call it *tse-ki*. The word porcelain is but little known there; except among a few workmen and mer-

chants; and seems derived from the Portuguese, *porcelana*, a cup.

Scaliger and Cardan, though generally of contrary sentiments, are yet agreed, that what the Romans called *vasa murrhina*, *murrina*, and *murrea*, which were first seen at Rome in Pompey's triumph, and afterwards became so very precious, were the porcelain of our times.

This may be true; but if the opinion be only founded on Pliny's description of those vessels, one would rather take them to have been made of a kind of precious stones, of a whitish colour, but variously veined and variegated, found in some parts of Parthia. *Oriens murrhina mittit*, &c. Plin. Hist. Nat. lib. xxxvii. cap. 2. See MURRHINE.

Be this as it will, it is certain, that both Cardan and Scaliger are mistaken when they tell us that porcelain is made of eggs and sea-shells, beaten small, and buried under ground for eighty or one hundred years. The account we shall here give will put that matter out of all question.

It is not known who was the inventor of porcelain; the Chinese annals, which commonly contain every thing in any respect memorable, are perfectly silent about it; nor do we know much more of the time of its invention: only it is certain it must have been before the beginning of the fifth century, the annals of Feou-lean relating that from the second year of the reign of the emperor Tam, about the year of Christ 442, the workers in porcelain of that province had alone furnished the emperors with it.

Porcelain is now made chiefly, some say wholly, at King-te-tching, a large and populous village near Jao-tcheou, in the province of Kian-gsi. See KING-TE-TCHING.

There is some indeed made in the province of Quang-tong and Fo-kien; but it is of little account, being far inferior in beauty and value to the porcelain of King-te-tching. That of Fo-kien is perfectly white without either gloss or painting. Attempts have been made to remove the manufacture from King-te-tching to Peking, and other places, but in vain; the porcelain made in the new manufactories never coming up to that of the old; so that King-te-tching has the honour of supplying the greatest part of the world with this commodity. F. du Halde assures us, that even the Japanese come to China for it.

There is a current opinion among the Chinese themselves, that the porcelain ware of former times was greatly superior to that which they make at present; and that the burying china in the earth for a long time adds to its beauty; but all this is founded on error. The truth is, that our merchants beat down the price of the ware, and thereby compel them to make a worse kind in general; but they are able to do as fine things now as ever. What gave birth to the opinion, that burying porcelain ware made it good, was, that finer pieces than ordinary are sometimes found buried. These are all precious vases, which the possessors buried by way of security in the times of civil war; and it is no wonder, that there are none but of the finest kind found buried on these occasions.

PORCELAIN, Manufacture of. Porcelain makes a very curious article in commerce, and not less so in natural history. Its manufacture for a long time passed as a mystery in Europe; and that in spite of all the endeavours of the Jesuit missionaries to penetrate into the secret. The veil, however, was at length drawn: and in a letter of F. d'Entrecolles to F. Orry, from Jauchew, dated September 1, 1712, and published in French, the whole process is described in all its circumstances; with an extract of which we shall here gratify the curious reader. In the manufacture of porcelain there are four things to be considered, viz. the mat-

ter it is made of; the art of forming the vessels, and other works; the colours with which it is painted; and, lastly, the baking or giving it the proper degree of fire. Each of which will make the subject of a separate article.

PORCELAIN, Materials of. There are two kinds of earths, and as many kinds of oils, or varnishes, used in the composition of porcelain. The first earth, called *kaolin*, (which see,) is intermixed with different corpuscles; the second, called *petunse*, or *petunse*, (which see,) is a plain white, but exceedingly fine, and soft to the touch. They are both found in quarries twenty or thirty leagues from King-te-tching; and hither these earths, or rather stones, are brought in a number of little barks, incessantly passing up and down the river of Jao-tcheou for that purpose. The petunses are brought in form of bricks; having been so cut out of the quarries, where they are naturally pieces of a very hard rock. The white of the best petunse is to border a little on green.

The first preparation of these bricks is, to break and pound them, first into a coarse powder with iron mallets, then in mortars with pestles that have stone heads, armed with iron, and wrought either with the hand, or with mills.

When the powder is rendered almost impalpable, they throw it in a large urn full of water, stirring it briskly about with an iron instrument. After the water has rested a little while, they skim off from the top a white substance formed there, of the thickness of four or five fingers, and dispose this scum or cream in another vessel of water. They then stir again the water of the first urn, and again skim it, and thus alternately, till there remain nothing but the gravel of the petunses at bottom; which they lay afresh under the mill, for a new powder.

As to the second urn, in which are put the skimmings of the first, when the water is well settled, and become quite clear, they pour it off; and with the sediment, collected at bottom in form of a paste, fill a kind of moulds: whence, when almost dry, they take it out, and cut it into square pieces, which are what they properly call *square* petunses; reserving them to be mixed with the kaolin in the proportion hereafter assigned.

These squares are sold by the hundred, but it is very rare to meet with them unfalsified; the workmen, who, like the rest of the Chinese, are arrant knaves in their dealings, usually mixing refuse along with them; so that they are commonly obliged to purify them before they can be employed.

The kaolin, which is the other earth used in porcelain, is much softer than the petunse, when dug out of the quarry; yet it is this, which, by its mixture with the other, gives the strength and firmness to the work. F. d'Entrecolles observes that some English or Dutch, having procured some petunses to be bought privately; upon their attempting to make porcelain at their return into their own country, could not succeed for want of taking kaolin along with it; which the Chinese being apprised of, said, humorously, "That the Europeans were wonderful people, to go about to make a body, whose flesh was to sustain itself without bones." The mountains whence the kaolin is dug, are covered without-side with a reddish earth. The mines are deep, and the matter is found in glebes or clods. The author is of opinion, that the white earth of Malta is not much different from the kaolin, except that it wants the silvered particles. The preparation of kaolin is the same with that of the petunses, except that the matter being less hard, less labour is required.

The oil or varnish, which makes the third ingredient in porcelain, is a whitish liquid substance; this is drawn from the hard stone, of which the petunses are formed; that

which is the whitest, and whose stains are the greenest, being always chosen for this purpose. The manner of preparing the oil is thus: the petunses, being washed, undergo the same preparations as for making the squares; excepting that the matter of the second urn is not put in moulds, but the finest part of it taken to compose the oil. To a hundred pounds of this matter they cast a mineral stone, called *shekau*, or *kekao*, resembling our alum; this stone is first heated red-hot, and thus reduced in a mortar into an impalpable powder; and serves to give the oil a consistence; which, however, is still to be kept liquid.

The oil of lime makes the fourth ingredient; the preparation of which is much more tedious and circumstantial. They first dissolve large pieces of quick-lime, and reduce it to a powder, by sprinkling water on it; on this powder they lay a couch of dry fern, and on the fern another of the flaked lime, and thus alternately, till they have got a moderate pile; which done, they set fire to the fern; the whole being consumed, they divide the ashes that remain on new couches of dry fern; setting them on fire as before. And this they repeat five or six times successively, or even more; the oil being still the better, as the ashes are oftener burnt.

In the annals of Fou-leam it is said, that instead of fern they anciently used the wood of a kind of medlar-tree; and that it was this gave the ancient porcelains that admirable hue, which the moderns cannot come up to for want of that wood. But this is become scarce in the country, and is no longer used. It is certain, however, the quality of the fern and lime contribute very much to the goodness of the oil.

A quantity of these ashes of fern and lime is now thrown into an urn full of water; and to a hundred pounds of ashes is added a pound of *shekau*, which dissolves therein. The rest being performed after the same manner as in preparing the earth of the petunses, the sediment found at the bottom of the second urn, and which is to be kept liquid, is what they call the *oil of lime*; which the Chinese esteem as the soul of the former oil, and which gives the porcelain all its lustre.

This oil is easily sophisticated by adding water to increase the quantity; adding, at the same time, proportionably of the same *shekau* to maintain the consistence. Ten measures of oil of petunse usually go to one of lime. To have the mixture just, the two oils should be equally thick.

PORCELAIN Vessels, forming of. The first thing is to purify the petunse and kaolin; which, for the first, is done after the manner already described in preparing the squares. For the second, as its softness makes it dissolve easily, it is sufficient, without breaking it, to plunge it in an urn full of water in an open basket. The dregs that remain are perfectly useless, and are emptied out of the work-house when a quantity is got together.

The work-houses are properly vast yards walled round, with sheds and other conveniences for the workmen to work under; as well as other buildings for them to live in. It is almost inconceivable what number of persons are employed in these works; there being scarce a piece of porcelain but passes through above twenty hands, before it comes to the painter's work-house; and above sixty before it be brought to perfection.

To make a just mixture of petunse and kaolin, regard must be had to the fineness of the porcelain to be made; for the finer porcelains, they use equal quantities; four parts of kaolin to six of petunse, for moderate ones; and never less than one of kaolin to three of petunse, for the coarsest.

The hardest part of the work is the kneading and tewing the two earths together; which is done in a kind of large basons, or pits, well paved, and cemented, in which the work-

men trample continually with their feet, relieving one another, till the mass be well mixed, grow hard, and become of the consistence required to be used by the potter.

The earth, when taken out of the basons, is kneaded a second time, but piece-meal, and with the hands, on large slates for the purpose; and on this preparation, in effect, it is, that the perfection of the work depends; the least heterogeneous body remaining in the matter, or the least vacuity that may be found in it, being enough to spoil the whole. The smallest grain of sand, nay, sometimes a single hair, shall make the porcelain crack, splinter, run, or warp.

The porcelain is fashioned or formed either with the wheel, like our earthen ware, or in moulds. See POTTERY.

Smooth pieces, as cups, urns, dishes, &c. are made with the wheel. The rest, *i. e.* such as are in relief, as figures of men, animals, &c. are formed in moulds, but finished with the chisel.

The large pieces are made at two operations; one half of the piece is raised on the wheel by three or four workmen, who hold it till it have acquired its figure; which done, they apply it to the other half, which has been formed in the same manner; uniting the two with porcelain earth, made liquid by adding water to it, and polishing the juncture with a kind of iron spatula.

After the same manner it is that they join the several pieces of porcelain formed in moulds, or by the hand; and after the same manner they add handles, &c. to the cups, and other works formed with the wheel.

The moulds are made after the manner of those of our sculptors; *viz.* of divers pieces, which severally give their respective figure to the several parts of the model to be represented; and which are afterwards united to form a mould for an entire figure. The earth they are made of is yellow and fat, dug out of its proper quarries, of which there is abundance about King-te-tching. It is kneaded like potters' earth, and when sufficiently mellow, fine, and moderately dry, beating it stoutly, they form it into moulds, according to the works required, either by hand, or on the wheel. These moulds are sold very dear, but they last a long time.

All the works made in moulds are finished by the hand, with several instruments proper to dig, smooth, polish, and to touch up the strokes that escape the mould; so that it is rather a work of sculpture than of pottery. There are some works on which reliefs are added, ready made, as dragons, flowers, &c. others that have impressions in creux; which last are engraven with a kind of puncheons. In the general, all porcelain works are to be sheltered from the cold, their natural humidity making them liable to break when they dry unequally.

To conceive the number of hands each piece of porcelain passes through before it is perfect, we shall close this article with what F. d'Entrecolles instances of a common tea-cup, before it be fit for the painter. The cup begins with the potter, who has the management of the wheel, where it acquires its form, height, and diameter. This operator has only three farthings sterling for a plate furnished with twenty-six cups; accordingly, they go out of his hands exceedingly imperfect, especially towards the feet, which are only unformed lumps of earth, to be afterwards cut with a chisel, when the cup is dry. When it comes from the wheel, the cup is received by a second workman, who fits it to its base. A third takes it immediately from him, and applies it on a mould, to bring it to its true form. This mould is on a kind of lathe. A fourth workman polishes the cup with a chisel, especially about the edges; and brings it to the thinness necessary to make it transparent; in doing which, he moistens

it from time to time, lest its dryness should make it break. When of its proper thickness, another workman turns it gently on a mould, to smooth its inside; taking great care that it be done equally, lest any cavity be formed, or it warp. Other workmen add some ornaments in relief; others, impressions in creux; others, only handles; as the quality of the cup requires. At last, they round and hollow the foot on the inside with the chisel; which is the function of a particular artist, who does nothing else.

This multiplicity of workmen is so far from retarding the work, that it is found, by experience, to go on the faster for it; as well as to be the better done; each workman, by a continual attention to the same thing, becoming very dexterous at it; besides saving the time of changing instruments, &c.

PORCELAIN, Painting of. The Chinese painters, especially those that meddle with human figures, our author observes, are all bad workmen; he adds, that the defect is scarcely any where so sensible as in the whapey, or porcelain painters, among whom, setting aside flowers and landscapes, which are sometimes tolerable, the greatest masters are not to be compared to ordinary apprentices among the Europeans, for the beauty and justness of design. But it is otherwise with the colours these whapey use; which are so exceedingly lively and brilliant, that there are but little hopes our workmen should ever come to vie with them.

The painting work is distributed among a great number of workmen, in the same laboratory: to one it belongs to form the coloured circle about the edges of the porcelain; another traces out flowers, which another paints: this is for waters and mountains alone; that for birds and other animals; and a third for human figures.

There are porcelains made of all colours: both with regard to the grounds, and to the representations upon them. As to the colour of landscapes, &c. some are simple; such are all blues, which are those most usually seen in Europe; others are mixed up of several tints; and others, again, are heightened with gold.

The Chinese, for a great many ages, used only white porcelain. The first colour they employed was blue, and after that they came into the use of all the rest. Their ancient blues were prepared by themselves from a kind of lapis lazuli; but we now supply them with the smalt so much cheaper, that it is no longer worth their while to make it themselves. They used to prepare this only by giving a gentle calcination to the stone, and then beating it to powder, and grinding it to the utmost fineness in mortars of unglazed porcelain ware, with pestles of the same.

The fine deep blue of the old porcelain ware of China is much valued by the curious; and it is much lamented, that the same colour is not used at this time. The art seems at present to be lost; but perhaps it might be recovered by trials.

It is certain that the Chinese have cobalt among them, and very probably they used a blue colour prepared from this, before they had any commerce with us: notwithstanding all the conjectures about their materials for colouring, this seems the most probable substance; and there is a way of preparing a colour from this, much superior to that now in use, which we call smalt.

Cobalt is a mineral containing arsenic, and a blue vitrifiable earth. The common way of preparing smalt is, by roasting this cobalt in a reverberatory fire. This disposes it to vitrify, and drives off the arsenic it contains in fumes, which, collected at the top, form true flowers of arsenic. It is very certain, however, from experiments, that if this arsenic could be preserved in the cobalt, the smalt would be

of a much finer colour; for there are some kinds of cobalt which yield smalt without previous roasting; and as the arsenic is in a great measure contained in these, the smalts are much finer coloured.

Arsenic added to smalt, while in fusion, greatly exalts its colour also; and there is a way of procuring smalt from cobalt without fire, only by dissolving it in an acid, and precipitating that solution with oil of tartar. The smalt thus precipitated to the bottom, is of a much finer colour than any prepared by fire; but it is much more expensive, and prepared in less quantity. It is very possible that the Chinese might have the art of making this kind of smalt before they knew us, and that to this was owing the fine blue of their porcelain ware: but when we trafficked with them, and they purchased smalt so much cheaper of us than they could make it themselves, they naturally discontinued the manufacture of their own finer kind, without considering how greatly inferior the colour was which the other yielded. If this be the case, it will be easy to revive this art, and the adding the true old china blue to our European manufactures, in imitation of porcelain, may give them a value which they have not at present.

The red, which the Chinese use, is made of our green vitriol, or common copperas, which they call *t/a-fan*. They put about a pound of this into a crucible; and lute on this another crucible inverted: this last has a hole cut in the top, which they keep covered or open at pleasure. They set this crucible in a furnace of bricks, so contrived, as to throw all the flame upon the lower vessel, in the way of our chemists' reverberatory furnaces. They make a large fire of charcoal all round it, and observe the hole at the top; for so long as there ascend thick black fumes through that, the matter is not sufficiently calcined. They watch the going off of this fume, and when there appears in the place of it a fine and thin cloud, they take away the crucible, the matter being then sufficiently burnt. They try this, however, by taking a little out, and examining the colour; if it is not sufficiently red, they let it remain longer in the fire. When they find that it is of a good colour; they take away the fire, and leave the vessels to cool; this done, they find a cake of red matter at the bottom of the crucible, and a quantity of a finer powder about its sides. They keep these separate, the latter being the purest, the finest, and the brightest colour.

One pound of copperas affords about four ounces of this colour, and this is the red which they manage in different shades, and vary so much. See *Blown REN*.

The Chinese have also a white colour, which they use in their figures painted on the china: the ware itself is naturally white, and the varnish, or oil of stone, is a great addition to its whiteness all over. But they have yet a way of making a much brighter and finer white than these, as may be seen in most of the fine china-ware, where there is any white in the figures. This white is made in the following manner: they collect on the shores of their rivers a sort of flint or agate, which is of a whitish hue, without veins, and tolerably transparent. It approaches very much to the nature of crystal, and probably crystal may be found to supply its place with us. They calcine this stone to a white powder, and to every ounce of this, when ground in their porcelain mortars to an impalpable fineness, they add two ounces of ceruss in fine powder: this they mix with the varnish, and lay on in the common way of other colours. This white mixture serves not only for the colouring white, but it is the basis of several other of those beautiful colours which we see on the china-ware, and which our manufacturers have been often perplexed what to make of. Their green colour

is made of copper rusted with acid ; and their fine deep violet colour is made of this green, by adding to it a due proportion of this white. It is not to be supposed that this effect is produced according to the common laws of mixing colours among our painters, for then the white and green would only make a paler green. But copper being a metal that as well gives a fine blue as a fine green, according to the nature of the substances it is mixed with, the white in this case alters the very nature of the green, and converts it into that fine and deep violet blue, which we may draw from copper by means of any of the volatile alkalies, such as spirit of sal ammoniac, spirit of hartshorn, spirit of urine, or any the like liquor. The workmen know how to bring this blue to any degree, by putting in different proportions of the two colours. There is not any admixture of them, that will not produce a blue of some kind ; but always the more of the green colour is used, the deeper the blue will be, and the less the paler. The yellow is made of an admixture of several drachms of this white, and three drachms of copperas, or more if they desire the colour to be deeper.

Most of these colours are mixed with gum water, for application ; with a little salt-petre, sometimes cerufs, or copperas, but more usually copperas alone, being first dissolved in the water. Indeed for porcelain, that are to be quite red, the colour is usually applied with oil ; i. e. with the common oil of the porcelain, or another made of the white flints.

These colours are laid upon the vessels when they have been once baked, but they do not appear till the second baking is over in their proper shades or tinges, and sometimes scarcely at all.

The black china called *umiam*, is much esteemed in the East, and particularly when it is ornamented with gold ; this colour looking better with that ornament than any other. The black is always laid on when the porcelain is first dried, and is prepared by mixing three ounces of the fine deep blue, with seven ounces of that fine varnish which they call *oil of stones*. This admixture gives a fine deep black ; but the proportion is varied, as the colour is designed to be more or less deep. When the colour is thoroughly dry, the vessels are baked, and when this is done, the gold is laid on, and the whole is baked again in a particular furnace made for this purpose.

The gold on this ware is never laid on alone, but managed in the following manner: they grind it in water to a fine powder, and leave it to dry in the shade ; they then mix with every ten grains of gold one grain of cerufs, and incorporating the whole with gum-water, they lay it on in the manner of other colours. See *GILDING of China-ware*.

If they would have the black degenerate into blue, they need only add less of the blue, and a little of the cerufs and agate white before described. They have two peculiar ways of applying the red, besides the common one, both which require a nice workman, and make the ware come very dear. They call one of these oils *red*, and the other *blown red*, which is very rare and of great price.

There is likewise a kind of marbled porcelain, called by the Chinese, who are very fond of it, *tsoutchi*.

It is generally plain white, sometimes blue, and has exactly the appearance of a piece of china which had been first broken, and then had all the pieces cemented in their places again, and covered with the original varnish. The manner of preparing it is easy, and might be imitated with us. Instead of the common varnish of the china-ware, which is made of what they call oil of stone and oil of fern mixed together, they cover this with a simple thing made

only of a sort of coarse agates calcined to a white powder, and separated from the grosser parts by means of water, after long grinding in mortars. When the powder has been thus prepared, it is left moist, or in form of a sort of cream, with the last water that is suffered to remain in it, and this is used as the varnish. Our crystal would serve fully as well as these coarse agates, and the method of preparation is perfectly easy.

The occasion of the singular appearance of this sort of porcelain is, that the varnish never spreads evenly, but runs into ridges and veins. These often run naturally into a sort of mosaic work, which can scarcely be taken for the effect of chance. If the marbled china be desired blue, they first give it a general coat of this colour, by dipping the vessel into a blue varnish ; and when this is thoroughly dry, they add another coat of this agate-oil. See *PARTY-China*.

There are several other kinds of porcelain ; but they are such as are rather for curiosity than use : the prettiest are the magic porcelains, whose colours only appear when filled with water, or some other clear liquor. These are made double ; the outside is white, and all laid out in compartments ; the inside is a solid cup of coloured porcelain ; though the cup is sometimes of glass, which has a better effect than porcelain.

The Chinese called this sort of china-ware *kiatfm*, that is to say, the concealed blue china.

The art is now in a great measure lost ; but there may be some guess made as to the manner in which it might be done at this time. The vessels which are to be made in this manner must be very thin : the colour must be laid on in the form of fish, or other animals or figures, on the inside, after the vessel has been once baked. After this colour has had time to dry, the inside of the vessel must have a second coat of the same earth, or stone-ware, of which the vessel is made ; and over this a varnish of the common kind. The consequence of this will be, that the figures of the fish, in a very strong colour, will be buried between two coats of the ware, which together form a complete vessel. The outside is then to be ground down almost to the figures, and when they begin to appear, a new coat of the varnish must be laid over this. The figures will then be obscure, and scarcely, if at all, perceivable ; but on filling the vessel with water, the transparency of the sides will be taken off, and the liquor will make a sort of foil behind, which will throw out the figures of the fish. This might be done in any ware tolerably clear and transparent. The porcelain of China would succeed better with it ; but the pains and nicety required are too great, and all the attempts lately made by them have miscarried.

The Chinese make a great variety of figures on the surfaces of the vases of white china-ware, and there is one kind of this greatly in esteem among them, in which there are flowers and other figures ; yet the surface is quite smooth, and the substance extremely thin. The manner of making it is this ; they first form the vessel of the finest materials, as thin as they can ; then, when they have polished it, inside and out, at the wheel, they put into it a stamp of its own shape, but cut with all these figures : they press this down so firmly on the yet moist vessel, that the impression is received in a very perfect manner ; and if the shape of the vessel be at all hurt, they take it into the wheel again to restore it. They then finish it with the knife and scissars ; and when they have made it as perfect as can be, they cover it with the fine white varnish within and without. This fills up all the cavities of the impression, and gives a perfectly smooth and even surface ; yet the thickness of this varnish

in the traces of the figures gives it a different white, and the whole figures are as finely and accurately seen, as if painted on the outside. This is an artifice that might easily be brought to bear among us, and several of our finer wares would make a pretty figure with it.

There are many things practised by the Chinese in their colouring and forming the several kinds of porcelain, which may be well brought into use among us, and give a new value to our own wares, even though we should never arrive at their art of making the thing itself. One kind of colouring easily introduced among us, would be what they call *hoan ton hoan*. This produces vessels of great beauty and price, and is done in this manner. The matter of which the vessels are made, for this purpose, need not be fine; they usually take any of the common vessels baked, without having been varnished, and consequently simply white, and without lustre. When these are intended to be of one simple colour, they need only be plunged into a liquid varnish of oil, as the workmen there call it, coloured with such ingredients as will strike the most lively tinges; but if it is to be coloured in compartments, as is usually the custom with this sort of china, it is to be done by the pencil. The usual way is to paint these in pannels, one green, another blue, and so on, and they make a very agreeable appearance. There requires no more to this, than the laying on the colours tolerably thick with a large pencil; but if the pictures of animals and plants are to be given, they are to be done with the most permanent colours, and the vessel being again well baked, becomes very beautiful.

The Chinese, who are deceivers in every thing, find the way of cheating very much in regard to this sort of china-ware. They paint the flowers of plants, and some parts of the birds, &c. in very bright colours, after the vessel has been baked. Vermilion is a fine colour, which they often add on this occasion; but they cannot use this before the baking, because it would be destroyed by the fire. These colours which are laid on afterwards cannot last, but soon rub off in the wiping, or using the things; the others last for ever; for they are laid on with the greatest heat of all, the vessels being put into the same furnaces to lay on these, as the other things are baked in for the first time.

Salt-petre, and powder of flints, are generally the things added to the colours thus laid on, to make them penetrate, and run properly. Thus, for the fine deep violet colour, which makes the greatest figure of all others on this ware, they mix together equal quantities of the fine azure, the powder of flints and salt-petre, all first powdered separately till perfectly fine; this is tempered with water, and then laid on with a pencil, and though it looks rough at first, it comes out of the furnace of as beautiful a glossy hue as any thing can be conceived. The yellow is made by mixing together three ounces of cerufs, and three ounces of powdered flints, and adding three, four, or more drachms of the red copperas, till the whole is of the proper degree of colour.

The white is composed only of powder of flints and cerufs, with a small admixture of the salt-petre, or it will succeed tolerably well without. These are all the particulars necessary to be observed for the making a sort of porcelain of great beauty, in which the nature of the ware itself is not concerned; so that it seems easy to imitate it with any of our own wares. *Obs. sur les Coûtumes de l'Asie*, p. 320, &c.

The several kinds of porcelains above-mentioned, being quite painted, with their several colours, and all the colours dry, are to be polished, to prepare them to receive the oil or varnish; which is done with a pencil of very fine feathers,

moistened with water, and passed lightly over, to take off even the smallest inequalities.

The oiling or varnishing is the last preparation of the porcelain, before it be carried to the oven: this is applied more or less thick, and seldomer or oftener repeated, according to the quality of the work. For thin fine porcelain, they give two very thin couches: to others one; but that one equivalent to the other two. There is much art in applying the varnish, both that it be done equally, and not in too great quantity. The couches on the inside are given by asperision, *i. e.* by casting in as much varnish as is necessary: those on the outside by immersion, or by plunging the pieces in a vessel of oil.

It must be observed, that the foot is not yet formed, but continues in a mere mass, till the work has been varnished: it is at length finished on the wheel, and when hollowed, a little circle is painted in it, and sometimes a Chinese character. This painting being dry, the foot is varnished, and the work now carried to the oven to be baked.

The varnish they lay on is so thick, that it often hides the colours, till the baking afterwards brings them out again: this is the case with the fine deep blues; we see none on the best china; it is all hid under the coat of white, and the vessel appears plain, till it has passed through the fire again; but then the colour appears deeper than when at first laid on. See *HOACHE*.

The china varnishes have been always famous; the manner of making which is said to be as follows: Take crude varnish, sixty ounces; common water, the same quantity; mix them well together till the water disappears; afterwards put this into a wooden vessel five or six palms long, and two or three broad; mix them together with a wooden spatula, for a whole day in the summer's sun, for two days if in the winter, and afterwards keep it in an earthen vessel, covered with a bladder. The water will not separate again: this is called the sun varnish.

The oil of wood, called by the Portuguese *azeite de pau*, is made in the following manner: Take twenty ounces of that oil, which they call oil of wood; and ten drachms of the oil of the fruit; boil these a little together, and the oil will look yellow; then let it cool, and add to it five drachms of quick-lime powdered. To make the first grounds, called *camisea*, take swine's blood and quick-lime powdered, of each an equal quantity; spread this mixture upon the wood, and when it is dry, smooth it with pumice-stones.

To make the black varnish: Take the varnish prepared in the sun, sixty ounces; stone black alum (supposed to be a sort of copperas) dissolved in a little water, three drachms; and seventy drachms of lamp oil, called by the Portuguese *azeite de Candea*. These things are all to be mixed together in a wooden vessel, putting the lamp oil in at twice, and stirring the whole together with a wooden spatula.

The pitch-coloured varnish is made in the following manner: Take oil of wood, crude, forty drachms, called *da pau*; of the lamp oil, called *da Candea*, crude, forty drachms; mix them together in the sun in a wooden vessel, in the same manner as the common varnish and water are ordered to be mixed in the first process.

To make the red varnish: Take ten drachms of cinnabar, twenty drachms of prepared varnish, and a little lamp-oil; mix them all together.

To make a yellow varnish: Take of the yellow colour ten drachms, prepared varnish thirty drachms, a little lamp-oil; mix all together.

To make the varnish of a musk colour: Take of the red varnish ten drachms, and of the black varnish four drachms; mix them well together. *Phil. Trans. N° 261. p. 524.*

These are the accounts sent to the great duke of Tuscany by the Jesuits in China. Dr. William Sherard communicated them to the Royal Society; and to render the accounts useful to the world, he presented them with the several substances mentioned; these are deposited in the museum of the society, and may serve as instructions to all who are curious in this art.

The Chinese have of late years discovered a new kind of varnish for their ware: they call this *tsékinyeou*, that is to say, the brownish gold varnish; it is of the colour of the brown images, or of what we call coffee colour. The novelty of this has made it much esteemed; it is made in the manner of all their other varnishes, by dissolving the finer part of an earthy substance in water.

The substance which they make it of is a common yellow earth: this they dissolve in water, and letting the coarser parts settle, they pour off the yet thick liquor, and what afterwards subsides from this is the pure and fine part, which they keep in form of a soft paste, or thick cream. They use this only to the thinnest and most delicate porcelain ware.

The manner of using it is this: they mix a quantity of this fine sediment with so much water as renders it thin and liquid, like the common varnish: this and the common kind are to be used together, so that each must be taken that they are nicely of the same degree of thickness: this the workmen try by dipping a petunse or brick of their earth into both, and seeing which comes out most covered; that which lies on the thickest is to be diluted with more water, or the other to be heightened with more of the earth, to bring them to the same standard. They are both judged to be sufficiently liquid when they enter the pores of the petunse. They then mix some of the oil of fern ashes and lime along with the brown varnish, and add as much of this mixture to the common varnish as they find upon trial will give such a colour as is required. The common proportion for the brown colour most esteemed at present, is two pints of the brown varnish to eight pints of the common; and to four pints of this mixture they add one pint of the varnish, or oil of fern. It might puzzle a stranger to their terms, to understand what these people meant by oil; but it is a word with them in use for any thing liquid; and they call all their varnishes so, though made of the powders of earths and stones mixed with water. They apply this varnish to the vessels by dipping them into it, and so completely covering them inside and out before they put them into the oven; and the baking gives a great brightness to the colour. This is the nicest part of the whole manufacture of the porcelain, and other wares of that kind.

The varnishes used by the Chinese are two; the one they call *oil of STONES*, the other *oil of FERN*; which see. They mix these together, and with great caution and delicacy apply them to the vessels all over equally, with a steady hand and a fine pencil.

PORCELAIN, Baking or Nealing of. There are two kinds of ovens used in baking porcelain; large ones, for works that are only used to come to the fire once, which is the common way; and small ones, for such as require a double baking.

The large ones are two Chinese fathoms deep, and almost four wide. They are formed of a mixture of three earths; one of which, yellow and common, makes the basis; the two others are scarcer, and dug out of deep mines, in which people can only work in winter. One of them, called *lautou*, is a very strong stiff earth; the other, *youtou*, oily.

The sides and roof of the ovens are so thick, that one

may lay the hand on them, when the fire is at its height, without danger of burning. At the top of the dome, which is in form of a tunnel, is a large aperture, to give vent to the flames and smoke, which mount up incessantly, as soon as fire is once set to the oven: beside the principal aperture, there are four or five small ones around; which, by being opened and shut, serve to augment or diminish the heat; like the holes in the chemists' furnaces, called *regifiers*. The hearth, which takes up the whole breadth of the oven, is placed in front, precisely against the opening of the door, and is two or three feet deep, and two broad; people passing over it on a plank, to go into the furnace to range the porcelain. As soon as the fire is lighted, the door is walled up, only leaving an aperture for the conveyance of wood. Lastly, the bottom of the oven is covered with sand, in which part of the first porcelain cases are buried. The oven itself is usually placed at the extremity of a long, narrow vestibule, which serves in lieu of bellows; the cold air and wind being thus driven directly in the face of each oven.

Each piece of porcelain of any note, is disposed in the furnace, in its peculiar separate case, or coffin. Indeed, as to tea-dishes, &c. the same case serves for several. The cases are all of the same matter with the oven; they have no lids, but serve each other mutually; the bottom of a second case fitting into the aperture of the first; and thus successively to the top of each column. Each coffin, which is usually of a cylindrical form, that the fire may communicate itself more equally to the porcelains inclosed, has, at bottom, a little lay of very fine sand, covered over with dust of kaolin, that the sand may not stick to the work; and care is taken, that the porcelain may not touch the sides of the case. In the larger cases, which hold the small pieces, they leave the middle vacant, in regard porcelains placed there would want the necessary heat. Each of these little pieces is mounted on a little mass of earth, of the thickness of two crowns, covered with powder of kaolin.

F. d'Entrecolles observes, that the porcelains are put in cases to prevent any diminution of lustre from the too violent effect of a naked fire; adding, that it is owing to those thick veils, that the beauty, or, as he calls it, the complexion of the porcelains, is not tanned by the heat of the fire.

As fast as the cases are filled, a workman ranges them in the cavity of the furnace; forming them into piles, or columns, of which those in the middle are, at least, seven feet high: the two cases at the bottom of each column are left empty, because being partly sunk in the sand, the fire has the less effect on them; and, for the same reason, the uppermost one is left empty. In this manner is the whole cavity of the oven filled with columns, excepting that part precisely under the grand aperture. In ranging the cases, they observe always to place the finest piles of porcelain in the centre, the coarsest at the bottom, and those that are high-coloured, and consist of as much petunse as kaolin, and in which the worst oil is used, at the mouth.

These piles are all placed very near one another, and are bound together at top, at bottom, and in the middle, by pieces of earth, in such manner as that the flame may have a free passage among them, and insinuate equally on all sides; in which a great part of the workman's art lies, and on which the perfection of the porcelain much depends. Another thing to be observed is, that an oven must never be set altogether with new coffins; but half one, half the other: the old ones at the bottoms and tops of the pile, and the new ones in the middle. Indeed it were better to have them all burnt in an oven apart, before they come to

be used for porcelain, as was anciently done. The cases, our author observes, are brought ready prepared from a large village on the river, a league distant from King-te-ching. Before they are burnt, they are yellow; and afterwards of a dark red.

When the oven is filled, they wall up the door, only leaving a small aperture for the throwing in of little pieces of wood, a foot long, but very slender, to keep up the fire: it is then heated by degrees for the space of a day and night; after which, two men, who relieve one another, continue to throw in wood without any intermission. To know when the porcelain is baked enough, they open one of the lesser holes of the oven, and with a pair of tongs take off the lid of one of the piles. If the fire appears very brisk and clear, and the piles equally inflamed, and especially if the colours of the porcelain, that is uncovered, dart forth a noble lustre, the coction is sufficient; they discontinue the fire, and wall up what remained of the door of the furnace.

If the oven be only filled with small porcelain, they take them out twelve or fifteen hours after the fire is extinct: if it be filled with larger, they defer opening it for two or three days. In this the modern practice differs from the ancient; in which the door was not opened till after ten days for the large pieces, and five for the small ones. One thing very surprising, and almost inconceivable, F. d'Entrecolles observes, is, that there are never found any ashes on the hearth of the oven, what quantity of wood soever is consumed. He adds another thing, which with him passes for equally strange, that the workmen employed about the furnaces, slake their thirst by continually drinking hot tea, with salt dissolved in it.

The Chinese make another kind of porcelain, which they paint and bake twice; and for this second baking they have a kind of little ovens on purpose. These ovens, when very small, are made of iron; or otherwise of a kind of bricks an inch thick, a foot high, and half a foot broad, made of the same earth with the porcelain cases. The biggest of these ovens do not exceed five feet in height, and three in diameter; and being made much in form of bee-hives, the bricks are arched a little, to form the curvity the better. The hearth is of earth half a foot high, formed of two or three ranges of bricks; and on this massive is the oven built. Around the oven, at the distance of about half a foot, is raised a shell of common bricks, joined to the oven itself by a kind of arc-boutant of earth, which serves to strengthen it. They usually build four or five of these ovens at equal distances from each other. At the bottom of the shell are holes to give air to the fire when lighted: at top is an aperture, which they cover up with a piece of the baked earth, when the porcelains are laid in the oven.

The porcelains here are not inclosed in coffins, as in the common ovens; the oven itself serving that purpose, and being so exactly closed, that they receive no other impression of the fire, but that of the heat of the charcoal disposed in the hearth, at the bottom of the oven, as well as at top of the vault, and in the interval between the oven and the shell, or brick-wall.

To prepare the porcelains for a second baking, they must have had their varnish in the common manner, and have passed the great oven: in this state they are painted with various colours, after which, without giving them any new varnish, they are ranged in piles in the little oven; setting the little ones over the larger, in form of pyramids.

The Chinese are very artful in their disposition of these, arranging them in the most compact manner, and putting

the little ones within the great ones; but great care is also necessary, that the vessels do not touch one another in the parts where they are painted, for the consequence of that would be the spoiling of both vessels, as the colours would run together. The bottom of one vessel may generally be placed on the bottom of another, though both are painted, because the rims are not painted, and they keep the painted parts from touching one another. High and narrow vessels, such as chocolate-cups, and the like, are very troublesome on this occasion. The method the Chinese workmen take with them, is this: they place a range of them, so as to cover the whole bottom of the furnace, and they cover this with a thin bed of broken china-ware, over which they place another row of the cups, and so on to the top, where they lay on no covering; they never bake any thing else with these cups, when they are of this kind of twice-baked porcelain.

This second baking is sometimes intended to preserve the lustre of the colours the better, and at the same time to give them a kind of relievé; but more usually its design is to hide defective places, by covering them over with colours; but the artifice is easily found out, by passing the hand over them.

When the workman judges his porcelains enough baked, he takes off the piece that covers the aperture; takes out the charcoal; and, when the oven is cold, the porcelain is so too.

How beautiful soever the modern porcelain may be, the taste for antiquity, which reigns in China, as well as in Europe, gives the ancient porcelain a value far above that of the modern.

It must be owned, the ancient seems finer as to the matter, more perfect as to the baking, and of a more pleasant cast, both as to the white of the ground, and the other colours; yet it is certain, the most able and discerning may be deceived in it; and there are workmen who make it their business to counterfeit the ancient porcelain, called *kutong*, in the modern.

The matter of the false *kutong* is a soft and yellowish earth, found near King-te-ching. There is nothing particular in the first part of the process, except that they are made thicker, and that they are varnished with an oil drawn from the yellow-stone, mixed with the common oil, which gives them a kind of sea-green hue. When taken out of the oven they throw it into a fatty broth, made of capons, &c., in which they boil it a second time; they then bury it in the filthiest sink they can find, for a month or six weeks, or more, according as they would give it the greater appearance of antiquity. Besides their thickness, and their colour, these false antiques resemble the true ones in this, that they do not resound when struck, nor ever give the least buzz when held to the ear.

Notwithstanding the vast quantity of porcelains made in almost all the provinces of the empire of China, they still continue very dear, though not near so dear as anciently. The Chinese annals tell us of times, in which a single urn cost ninety or a hundred crowns on the spot. What chiefly occasions the extraordinary price of this commodity, especially in Europe, is, beside the great profits of the merchant in Europe, and their factors in China, that it rarely happens an oven succeeds throughout; that it is frequently quite spoiled, so that upon opening it, in lieu of fine porcelains, is found a hard unformed mass, into which both the porcelains, and their coffins, are converted, either by excess of heat, or some ill qualities in the matter.

Another reason of the dearth of porcelain is, that the ingredients it is made of, and the wood with which it

is burnt, grow more and more scarce. One may add a third reason for the excessive price of porcelains to the Europeans; and it is this: that most of those sent to Europe are formed on new models, frequently very capricious, and difficult to succeed in; which yet for the smallest defects are turned on the manufacturer's hands; and he, not being able to dispose of them to the Chinese, because not to their taste, nor to their use, is forced to charge the porcelain he delivers the higher, to pay himself for those refused.

The art of making porcelain is one of those in which Europe has been excelled by oriental nations. However, earthen-ware has been made, for several years past, in different parts of Europe, so like the oriental, that they have acquired the name of porcelain. The first European porcelains are said to have been made in Saxony and in France; and afterwards in England, Germany, and Italy; all of which differed from those of Japan and China, but each possessing its peculiar character. The first person, who seems to have made this manufacture the object of scientific attention, was M. Reaumur; and he communicated his researches in two Memoirs to the Academy of Sciences, in 1727 and 1729. Having broken pieces of the Japanese, Saxon, and French porcelains, he examined the difference of their grains or internal structure. The grain of the Japanese porcelain appeared to him to be fine, close, compact, moderately smooth, and somewhat shining. The grain of the Saxon porcelain was found to be still more compact, not granulous, smooth, and shining like enamel. And the porcelain of St. Cloud had a grain much less close and fine than that of Japan, shining little or not at all, and resembling the grain of sugar. In order to determine their difference still farther, he exposed them to a violent heat; and found that the Japanese porcelain was unaltered by the fire, and all the European porcelains were melted. This essential difference suggested to him the most just and regular idea, that has yet been formed of the porcelain or china-ware, viz. that it is a half vitrified substance or manufacture, in a middle state between the common baked earthen-ware of our vulgar manufactures, and true glass. This is the essential and distinctive character of porcelain; and it is only by considering it in this light, that we are to hope to arrive at the perfect art of imitating it in Europe.

The determining the due degree of heat for the baking the china-ware, and the finding out the proper time it should remain in that heat, are two very essential points in the manufacture of this elegant ware. Perhaps our English attempts to imitate it would be brought nearer the perfection we are aiming at, by a just regard to these particulars, than by many other less material articles, about which we seem more solicitous.

This attempt is to be made on these principles in two different manners: the one by finding some appropriated matter on which fire acts with more than ordinary strength, in the time of its passing from the common baked state of earthen-ware into that of glass. The other is to compose a paste of two substances reduced to powder: the one of which shall be of force to resist a very violent fire, so as not to become vitrified in it; and the other, a matter very easily vitrifiable.

In the first case, the matter is to be taken out of the fire at the time when it is imperfectly vitrified; and in the other, the compound mass is to remain in the furnace till the one substance, which is the more easily vitrifiable, is truly vitrified; and being then taken out, the whole will be what porcelain is, a substance in part vitrified, but not wholly so.

The first method is that by which the European porcelain

has generally been made; and though that of St. Cloud, and some other places, has been very beautiful, yet it is always easy to distinguish even the finest of it from the china-ware, and the nature of the two substances appears evidently different; these owing all their beauty to their near approach to vitrification, are made to endure a long and violent fire, and are taken from it at a time when a very little longer continuance would have made them perfect glass; on the contrary, the china-ware being made of a paste, part of which is made of a substance in itself scarcely possible to be vitrified, bears the fire in a yet much more intense degree than ours, and is in no danger of running wholly into glass from it.

The two substances used by the Chinese are well known by the names of *petunse* and *kaolin*; and on examining these, it appears very evident that we have in Europe the very same substances, or at least substances of the very same nature, and capable of being wrought into a porcelain equally beautiful and fine. Mem. Acad. Scienc. Par. 1739. See KAOLIN and PETUNSE.

These are the two different semi-vitrifications, on one or other of which all the European manufactures have hitherto been founded; and it is easy from the knowledge of these principles to determine, on breaking a piece of the china of any of our manufacturers, by which of the two processes it is made. If it is made by seizing the half-vitrified mass of a substance, which would soon after have been wholly vitrified, then the putting it in a crucible, into an equal degree of fire, will soon turn it wholly into glass. This is the case of most of our European porcelain; but if it be made of two ingredients, the one of which is not vitrifiable, or at least not by such fires, then the matter will melt, but will not vitrify. This is the case with the Chinese porcelain, which if kept in fusion a long time, yet when cold is china-ware still; so that this is evidently made of two such different ingredients.

Besides these methods, there is yet another, of late invention, which makes a very beautiful china; and which, if it does not afford vessels equal to those of china, yet will afford them nearly approaching to those, and at a considerably smaller price. This method consists in reducing glass to china. See GLASS-PORCELAIN.

Macquer, the author of the Chemical Dictionary, observes, that M. Reaumur has erroneously confounded the Saxon porcelain with the other fusible porcelains in Europe. For though it contains, as every porcelain does, particularly that of China and Japan, a fusible substance, which has been completely fused in the operation of baking, and to which it owes its density and internal lustre; yet it contains also a large quantity of a substance absolutely infusible, from which it receives its admirable whiteness; its firmness and solidity, during the baking, supplying the place of the oriental kaolin, and contracting its dimensions in a considerable degree, while it incorporates with the fusible substance. He has actually found, that this porcelain cannot be fused, unless by a fire capable also of melting the best Japanese porcelain. And he observes, that it is superior to the oriental in the smoothness, lustre, and less granulous appearance of its internal surface. The manufacture of Saxony has been long established; and that at Meissen, a few miles from Dresden, has produced porcelains painted and enamelled in such perfection, that they have been reckoned more beautiful, and sold at a higher price than even those of China.

The invention is said to have been owing to an alchemist called Botticher, who, being confined in the castle of Konigstein by the king of Poland, on a suspicion of being

master of the philosopher's stone, had leisure sufficient, not indeed to make gold, but to invent a ware, which, by the excellence and value of it, considerably enriches the country. He died in 1719, but it seems that he only invented the white fort; the art of making brown and blue porcelain not having been discovered till the year 1722.

Porcelain is also made at Vienna, Frankendal, and lately in the neighbourhood of Berlin; all which are made of the same kind of materials with those of Saxony. In Italy there are also manufactures of porcelain, at Naples, and Florence. In France they have had manufactures of this kind for many years: porcelain was made at St. Cloud, and in the suburb of St. Antoine at Paris, before M. de Reaumur's publication; but though beautiful, it was of the vitreous and fusible kind. Since that time, considerable manufactures of it have been established at Chantilly, Villeroy, and Orleans, the porcelains of which have a distinguished merit; but those produced in the king's manufactory at Sevres are said to do greatest honour to France, on account of their shining, white, beautiful glazing, and coloured grounds.

M. Guettard, who has published an account of his discoveries in the Memoirs of the Academy of Sciences for the year 1765, seems to have been one of the first who, since M. Reaumur, found in France a kaolin and petunse of the same nature as the Chinese: the former is a white argillaceous earth filled with mica; the latter a hard quartzose stone. The count de Lauraguais has also so far succeeded in his attempts in this way, that some pieces, presented by him in 1766 to the Academy of Sciences, were declared to resemble the porcelain of China and Japan in solidity, grain, and infusibility, more than any other that had been made in that country, though it wants the whiteness and lustre observable in the ancient Japanese porcelain.

In the first attempt to make porcelain in France and in this country, it possessed very inferior qualities to that made in China and at Dresden: it was much more fusible, and had an open fracture. In consequence of these defects, it has been distinguished from genuine porcelain by the name of soft and tender porcelain.

It is painful to confess that we have not as yet produced any thing superior to the latter in this country. The French, till the discoveries of Reaumur and others, did not make the real porcelain.

Porcelain appears to have been first brought into Europe by the Portuguese, but at what period it is difficult to say; but doubtless long before any attempts were made by the Europeans to manufacture it.

The first attempt was, as we have already observed, by baron de Botticher, a German chemist. In making some crucibles, he found they assumed by heat the character of porcelain. This gave rise to the manufactory, which is still carried on at Dresden; and it is curious to have to remark, that their materials, from the first, proved to be similar to those employed in China.

The success of this manufactory soon produced other attempts in France and this country. It was known that the Chinese employed two substances for the body of the porcelain: one called kaolin, having the ductile properties of clay; and the other named petunse, which was a white stone, and did not produce a paste in itself.

A French missionary in China, of the name of d'Entrecolles, sent over to France specimens of the kaolin and petunse, with such instructions as he could collect. It seems that very little was gained by this. They did not at first succeed in finding similar materials in France; and if they had, the account given them by d'Entrecolles was

so defective, that it rather misled them than otherwise. Very little progress was made by the French, till the celebrated Reaumur, as we have already mentioned, investigated the subject. His first object was to examine the fracture of the different porcelains. He found the fracture of Chinese porcelain to be very compact, but slightly granular; the Dresden more compact, and resembling enamel; that of St. Cloud, which was the best attempt after the Dresden, had an open granular fracture, more resembling fugar. His next object was to ascertain their relative degrees of fusibility. He found the Chinese to withstand the greatest heat without fusion, while the others yielded to the ordinary heat of furnaces. He concluded from his experiments, that it was essential to have two substances for the formation of porcelain. The one should constitute the body or skeleton of the substance, by being infusible with the greatest heat of the furnace employed; the other substance should, at the greatest heat required, become fused, and enveloping the infusible parts, constitute the semi-transparency so conspicuous in porcelain. The first of these properties he found to exist in the kaolin, and the second in the petunse of the Chinese.

It was not, however, till after the researches of Macquer and Montigny, that the French porcelain became fit to compare with that of Dresden and the Chinese. They put the manufactory at Sevres in possession of the means of employing substances similar to kaolin and petunse, with as much success as the Chinese.

If, agreeably to the principle laid down by Reaumur, porcelain is constituted of two substances, one of which is infusible, and acts as a prop or skeleton, while the other, which is fusible, cements and binds the infusible parts together; it will be easy to conceive, that a great variety of this species of earthen-ware may be formed with substances possessing different degrees of fusibility. The best and true porcelain, however, appears to be formed when the fusible part of the porcelain requires the greatest heat for that purpose. This is the petunse of the Chinese, and is similar, if not the same, with the feldspar which is found in Cornwall, and employed in most of the manufactures here. The other substance to which the porcelain mass owes its ductility, is called porcelain clay, and by some porcelain earth. This is nearly the same with the kaolin of the Chinese. Sometimes the substance known by the name of soap rock, and also called steatite, is employed with the kaolin, or porcelain clay. This is said to give firmness to the infusible part of the porcelain. A substance similar to this last is in some cases used by the Chinese. The body of the best porcelain should, therefore, be formed of certain proportions of porcelain clay with the feldspar. The less of the latter, the more difficult it will be to bring about the semi-transparency by heat. But if the feldspar were in great proportion, the vessels so formed would shrink in the fire, before the diaphanous property was produced. If vessels were made solely of the porcelain clay, without any feldspar, they would possess great whiteness and firmness, but not the least transparency. Hence this clay answers very well for crucibles or other vessels required to resist great degrees of heat. Porcelain made of the best proportions of these two substances, we have before observed, is called hard porcelain. In some parts of France, and in this country, the porcelain is made of these substances in part, but other materials are employed to give the required transparency at a lower temperature. This has received the name of soft porcelain. The receipts for making soft porcelain are very numerous; scarcely two manufacturers using the same, although each keeps his own a profound secret, and thinks it the best.

They all use more or less of porcelain clay and feldspar. The former is often called Cornwall clay, the latter Cornwall stone. This they employ in different proportions with bone ashes. The latter constitute the infusible part, while the feldspar, which is used in greater proportion, fuses to give the transparency. Some use gypsum in their composition, to give it an opal appearance. All these porcelains are so fusible, that they are obliged to be glazed with a substance containing oxyd of lead, which must ever be considered as objectionable in the manufacture of vessels used in domestic life. The true porcelain is glazed with feldspar, which can only be effected when the fabric will bear a heat sufficient to make the coating of feldspar flow thinly over the surface.

It may be proper here to state some facts respecting the porcelain clay and the feldspar, which may be a means of improving upon the materials which nature furnishes.

The Cornwall stone is a species of granite in a state of decomposition, and principally consists of feldspar. The porcelain clay is found in situations where this decomposition is constantly going on, and the clay is separated by the action of water, which washes these parts miscible with that fluid into pits made, in succession, for the purpose. In order to give some idea of the similarity between feldspar and porcelain clay, we will give the following analysis by Vauquelin.

Feldspar.	62.83	Silex
	17.02	Alumine
	3	Lime
	1	Oxyd of iron
	13	Potash
	96.85	
Porcelain clay.	55	Silex
	27	Alumine
	.5	Oxyd of iron
	14	Water
	2	Lime
	98 5	

Before it was suspected that the alkalies entered into the composition of minerals, the analysis of these two substances afforded nearly the same substances, offering very little in their proportions. In the analysis of feldspar, however, a great loss was always observed, which could not be accounted for, but which is now found to be potash. This satisfactorily explains the fact of porcelain clay, from which the alkali has been separated by the decomposition of the feldspar, being infusible with the greatest heat of furnaces; while the feldspar itself, which contains potash, melts at little more than a red heat. These facts will, no doubt, give some valuable hints to the scientific manufacturers of porcelain.

It may seem to the reader a little strange, why the soft porcelain, which is a vague and artificial composition, should be made at all, and why the simplest proportions of the clay and Cornwall stone should not be universally employed. In answer to this we may state, that in none of the manufacturing arts in which fire is an important agent, has there been less skill displayed, or less improvement made, than in the potter's kiln, which from its construction is limited to a very low degree of heat, and has besides many other defects, which must ever be an obstacle to the manufacture of porcelain. On this subject we shall give some observations in another place. We shall now proceed to

go through the different manipulations for many vessels of porcelain, which will be the same whatever may be the nature of the materials.

Previously to the different materials being mixed which are to constitute the mass from which the vessels are to be formed, they are first ground between two surfaces of chert or porphyry: the first of these is a hard siliceous stone, found in Derbyshire, and other places. The passive part of this machine consists of these stones, which occupy the bottom of a cylinder, about twelve or eighteen inches in depth, and from six to ten feet in diameter. In the middle of the cylinder works an upright shaft, with arms at right angles, on which are placed the active stones, so that by the rotation of the latter upon the passive stones, the substance, such as flint or feldspar, is ground. As much water is always present as keeps the substance grinding to the consistency of pulp.

After the substances have been ground in this way to a certain fineness, which also effects their intimate mixture, the pulp is passed through a sieve of fine silk. The operation is called *laxoning*. This renders the pulp very fine, and prepares it for evaporation.

The evaporation of the water is performed in a vessel made of fire-brick; its surface is great, and the depth not more than twelve to eighteen inches. The breadth is about six feet. The fire is at one end, and the flame runs under the whole length, to the chimney at the other end. The heat is given very slowly to the pulp, till the mass will admit of being cut out with a spade in square masses. These masses are a little too soft for working, and require another operation, called wedging or slapping. This consists in separating each of these squares with the hand, and slapping them violently together on different sides to those immediately separated. This is repeated till the mass becomes perfectly uniform. In mixing water with clay or any other dry substance which requires to be thoroughly penetrated by that fluid, it is found that considerable time is necessary to do it effectually for this purpose. It is common, after the first wedging, to allow the mass to remain undisturbed for some time. This allows every part of the substance to be saturated with water, and the mass requires that degree of uniformity and tenacity, by which it is worked with greater facility. Previously to being worked it undergoes another wedging, by which it acquires the proper consistency for working into utensils of different kinds.

This branch of the art is divided into three departments, namely, throwing, pressing, and casting.

Throwing is performed upon a machine called the potter's lathe. This consists of an upright shaft, about the height of a common table, on the top of which is fixed a circular piece of wood, of a breadth sufficient for the widest vessel to stand upon. The bottom of the shaft runs in a step, and the upper part in a socket a little below the circular board, so that the shaft and the board turn together. The shaft is turned by a pulley, placed upon it by a band, which passes from it to a wheel about ten times the diameter at some distance. This latter, being turned by a handle, gives motion to the lathe. The masses to be thrown are first weighed out. The thrower places the mass on the face of the circular board, which is in motion, and shapes it by his hand and fingers previously wet, aided by the circular motion, to the desired form. He then cuts it off at the base by means of a piece of fine brass wire, with a handle at each end. The vessels thus roughly formed are placed in a situation, where they dry gradually to a certain extent. During the drying of the vessels, there is one point in which the clay possesses a greater tenacity and hardness than at any

other period. This is called the green state. At this period they are taken to another lathe, which, to distinguish it from the throwing lathe, is called a turning lathe. The vessel is here slightly attached to a wooden chock by wetting, and then turned into its proper shape with a very sharp tool, which gives it great smoothness at the same time. After this it is slightly burnished with a smooth steel surface. Such vessels as require to have other parts attached to them, such as handles, spouts, &c. undergo this operation when they come from the turning, this being the proper state of dryness for that purpose. The handles are first made of the proper size and shape in moulds of plaster: they are then stuck to the vessels, by means of a pulpy mass of the same material, of the consistency of thick cream. In this state it is called slip. The surface where the union is formed is then smoothed with a wet sponge. The vessels are now taken to the stove to be thoroughly dried.

When they are perfectly dry they are examined, to see if any parts be still rough; indeed, some places cannot be made perfect in the green state. The perfect finish is given by rubbing the rough parts with a small bundle of hemp.

The throwing and turning can be employed only for such utensils as are of a circular form. When the form is otherwise, recourse is had to moulds. The moulds are made of plaster, and sometimes, for delicate work, of sulphur. The clay is first made into a flat piece of the thickness of the vessel: it is then gently pressed into one-half of the mould, a similar piece being pressed into the other half. The two halves are now united together, and the plaster moulds removed. The vessels now undergo repairs, and are set to dry, to the same degree at which the thrown articles are turned. The vessels are now all finished as to their form and the different appendages, which are put to them by means of the slip. These are now fully dried, and finished by rubbing with hemp.

The casting operation consists in pouring the clay, in the state of pulp or slip, into plaster moulds, which are kept in a certain state of dryness. These moulds are made in two halves, and fit together in the same way with those used for casting metals: the pulp is poured in till the cavity is quite full, and suffered to remain for a certain time, which is more or less according to the intended thickness of the vessel: that part of the pulp which is contiguous with the plate soon loses its excess of water, which is absorbed, leaving the clay in that part so stiff, that when the unchanged pulp is poured back, a portion remains, which, when removed from the mould, constitutes a vessel, the exterior of which has the exact form of the mould; the thickness of the clay being more or less, according to the time the pulp remains in the mould.

The articles formed in this way are dried to the green state, similar to those above-mentioned, at which period the parts to be united are put together with slip.

It is in this way that the greater parts of those elegant figures and ornamental works are formed, and sold in a state of white biscuit. These are made in the greatest perfection at the Derby porcelain works. The imitation of flowers and foliage is exquisitely managed. Each of the leaves and petals being made in a separate mould, renders this kind of work very expensive.

All the various kinds of work made by the different processes, after being finished, so far as regards their shape, are placed on a stove to keep them in a hot state for burning, till there is a sufficient quantity to fill the kiln.

The next process is that of burning or firing, which consists in giving the porcelain a very considerably red or almost white heat, by which it acquires its hardness, and

possesses at the same time great whiteness, and is semi-transparent. In this state it appears like very white sugar, and it is called biscuit.

The potter's kiln, which that used for porcelain strictly resembles, is built in the form of an erect cone, with an opening at the top for the escape of smoke. A certain part within the cone is built with fire-bricks, within which the vessels containing the porcelain are piled one upon another. These vessels for defending the ware from the immediate action of the fire, are called *faggars*, which in all probability is a word corrupted from *safeguards*. They are cylindrical vessels from twelve to eighteen inches in diameter, from six to twelve inches deep, and from one inch to one and a quarter thick. These dimensions, however, vary with the size of the articles to be burnt.

The bottoms of the faggars are slightly covered with a fine white sand, which does not change by the fire. The particles act like so many little spheres, allowing the porcelain to touch the faggar's bottom only in a few points.

When the ware is put into the faggars, they are to be piled up in the kiln, each superior faggar serving as a lid to the one beneath it. These piles are by the workmen called *hangs*. Before one faggar is laid upon another, a ring of soft clay is laid upon the edge of the lower one; so that the upper one, being placed upon it, secures the ware in the same from any dust or smoke. The rings of clay so placed between the faggars, are called *wads*. The uppermost faggar is, lastly, covered by a lid, or an empty additional faggar.

The piles in the kiln being completed, the next thing is to apply the fire. This is made with wood on the continent, and probably in China; but in this country the kilns are fired with pit-coal, that producing the most flame being preferred for this purpose.

The fire-places are generally several in number, more or less, according to the size of the kiln. They are made at the bottom of the cone, on the outside, and the flame penetrates the kiln through a horizontal flue, and then ascends perpendicularly, surrounding the piles of the faggars, till it makes its exit at the opening in the top of the cone. The want of a sufficient quantity of oxygen in the body of the kiln does not afford a perfect combustion of the smoke. This not only limits the heat which is so essential, but is the cause of immense volumes of unburnt matter escaping from the chimney, to the annoyance of the surrounding country. (See the kiln described under POTTERY.) The fire is kept up from twenty-four to forty-eight hours, when the kiln is suffered to cool before the faggars are disturbed.

The porcelain is now taken from the faggars, and cleared from any particles of sand which may have adhered to it. In this state it is called biscuit. All the common earthen-ware and the soft porcelain are so porous in the state of biscuit, as to be permeable to water, and, in consequence, would be useless, without the surface being covered with glaze, in order to fill up the pores.

The glazes used for soft porcelain, and the common earthen-ware, are mixtures of some earthy substance, such as flint or clay, or both combined, with some vitrifiable metallic oxyd, in order to give it the necessary fusibility. The oxyd of lead is generally employed for this purpose, with sometimes the addition of oxyd of tin or arsenic, in order to give the glaze a certain degree of opacity. In the hard porcelain, such as that of China and Dresden, the glaze does not contain lead or other metallic oxyd, except we call potash the oxyd of a metal. The porcelain being formed of such proportions of the porcelain clay and the felspar, as to bear a great degree of heat, a glaze may be employed, much

less fusible than those employed for the soft porcelain. The glaze of such porcelain is, therefore, the felspar alone. We have before stated, that the felspar owes its fusibility to a certain portion of potash which it contains: it might hence be inferred, that the common fusible glaze could be formed by combining potash or soda with earthy substances, in greater proportions, and thus obviate the use of oxyd of lead entirely, which, from its poisonous qualities, is very objectionable. Such an expedient has often, and is still resorted to, by the manufacturers of earthen-ware; but it is found, that when a glaze contains more than a certain proportion of alkali, it does not undergo the changes of expansion agreeably with the body on which it is laid, and is apt, in consequence, to crack. It is not uncommon to see some of the very common species of earthen-ware appear covered with cracks on the surface. Whenever this happens, the body soon becomes penetrated by grease, or any other substance applied to the vessels so glazed. The oxyd of lead, in a certain proportion, forms a more permanent glaze, and is less liable to the above objection; but we find that acids, particularly vinegar, dissolve the lead in such glaze, and has, in many instances, been productive of bad consequences. The glazing used for the soft porcelain in general contains lead, and differs very little from that used for common white earthen-ware, which is generally called white enamel. Since the substance known by this name enters into the composition of the porcelain glaze, and also into the flux used as a vehicle for the colours, we will give the process for forming white enamel, as recommended by Chaptal in his *Chemistry applied to the Arts*. Take equal parts of lead and tin, and expose them on a melted slate till they are completely oxydated. Let the powder so formed be ground with water, and well washed from any impurities, which will be known by the water being clear. This fine powder being dried, is kept free from dust. This being done, take the whitest flints, and fuse them with salt of tartar, or carbonat of potash; the latter being in such proportion to the flint, that the compound may be soluble in water. If to the solution of flint so formed, muriatic acid be added till flint ceases to be precipitated, the precipitate may be considered as pure flux. This being well washed and dried, is kept for use. Of the first preparation of tin and lead, take 100 parts; of the prepared flint, 100 parts; to these add 200 parts of carbonat of potash: fuse the whole in a clean white crucible, and pour it on a clean slate: when cold, reduce it to a fine powder, and keep it for use.

This preparation is intended for the nicest purposes. For the common earthen-ware less pains would be taken in preparing the flint and the oxyds of lead and tin. In future this preparation will be called white enamel. If the porcelain to be glazed will not bear a great heat, the white enamel may be used alone as glazing. The three following are recommended by count Milly in his work on porcelain. First, very white quartz, 8; white enamel, 15; and calcined gypsum, 9. The second is, 17 of quartz; 16 of white enamel; and 7 of gypsum. The third is, 11 of quartz; 18 of enamel; and 12 of gypsum.

These possess different degrees of fusibility, according to the lead they contain. The very hard porcelain, such as that of Dresden or China, is glazed with felspar alone: for this purpose, the felspar is reduced to a fine powder, similar to that constituting the glaze already mentioned.

Having now pointed out the material for glazing, we will shew the manner of laying it upon the biscuit, in which state we left it when taken from the kiln, and cleared from any small particles adhering to it. The material for glazing is to be mixed with water till it is about the con-

sistence of fresh cream. The powder should be extremely fine, that it may remain in suspension. The mixture, besides this, should be agitated all the time of glazing, in order to keep the fluid of an uniform thickness. The biscuit is dipped into the glaze. On taking it out, the piece of porcelain is to be turned hastily into different positions, in order that the covering may be uniform. The biscuit, from its porosity, absorbs the water from the solid part, leaving a coating which is of sufficient hardness to remain permanent till it is exposed to the fire. Those articles which are coloured in any part with cobalt, and sometimes the black or brown colours, require to be painted with the colouring matter before they are dipped in the glaze. In these instances the colours are seen to the greatest advantage through the glazing.

The next process is the firing. To fuse the glaze for this purpose, the coated ware is placed in clean faggars, such as those used in the first firing. That part of the porcelain which is to rest upon the bottom of the faggar has the glazing rubbed off. If this were not the case, the glaze would fasten it to the bottom of the faggar. The faggars are now to be piled up in the same kiln, and in the same manner as employed in the first firing, but the temperature not so high: it should be, however, just sufficient to give perfect fusion to the glaze. The heat employed for the felspar glaze, in the manufacture of hard porcelain, is much greater than for the glaze of the soft kind, although the relative degrees of the biscuiting and glazing heat may be nearly the same in each kind. In this state the porcelain has attained all its useful qualities, the painting and gilding requiring an additional process. Before we speak of the method of laying on the colour, we shall give some account of the preparation of the colouring materials, and the proper flux by which the colour is united to the body. The different colours are produced by metallic oxyds: these bodies are, in general, capable of assuming a vitreous form with different degrees of facility. The oxyd requires to be accompanied by a certain vehicle, called a flux, which has the effect of rendering the whole more fusible than the first or proper glazing already described. Some manufacturers exclude lead from their flux used with the colour, as being injurious to the colour; others employ it constantly. Certain it is, however, that in its tendency to promote the fusion of the under glaze, the colour becomes diluted, particularly when too much heat is employed.

The flux which contains lead may be formed by adding a little borax to the white enamel already described, fusing the mixture, and reducing it, when cold, to powder.

The flux given by Chaptal for this purpose consists of glass in powder, free from lead, 20 parts; calcined borax 11 parts; and purified nitre 22.

The flux, whatever may be its composition, is to be ground with some metallic oxyd into fine powder. It is then mixed with oil of lavender, or, what is cheaper and better, old oil of turpentine. The latter is merely to give that consistency to the whole, which will make it, in the best state, to be laid on the work with a camel's hair pencil.

As the preparation of the metallic oxyds to be used as colouring matter, require great nicety in their preparation, we will give some account of the best means of their preparation, before we proceed to state the different processes of painting porcelain.

Colour produced by Gold—The oxyd of gold has been considered a valuable substance in producing the carmine, rose, and purple tints. The most common preparation is the purple powder of Cassius: it is prepared by dissolving the

gold in aqua regia, formed of equal parts of nitric and muriatic acids. Next dissolve tin in the same menstruum, keeping the vessel in which the solution is formed as cool as possible. The solutions of each should be perfectly clear. First dilute the solution of gold with three or four times its bulk of water; then add the solution of tin by a very little at a time: a purple precipitate will fall down. Continue to add small portions of the solution of tin till no more purple precipitate is produced. It must be observed, that the solution of tin should be kept close stopped from the air, between the intervals of using it; as the presence of oxygen would soon render it unfit for forming the purple powder. This powder is well washed by pouring hot water upon it, and drawing off the clear liquor from time to time. It is then to be dried and kept for use. The yellow oxyd of gold is sometimes used for painting. It is obtained by precipitating it from its solution by an alkali, or by lime water. The precipitate is to be washed and dried in the same way as the last, and kept for use.

When either of these substances is used, they are to be intimately ground with the flux above-mentioned, in quantity proportionate to the intensity of the colour required. The mixture is then used by some manufacturers in that state for painting. Others fuse the mixture into a glass, and again reduce it to powder. In either state it is mixed with oil of turpentine till the mixture assumes a proper state for the pencil. The figures are painted upon the glazed porcelain, the volatile part evaporates, leaving the colouring matter with a small remain of resinous. In this state the goods are ready for a third firing, to fix and bring out the colour by the fusion of the vitreous colouring matter. When the fusibility of flux is greater than common, and the heat moderate, the purple colour is produced; the rose colour requiring less flux and more heat.

The purple colour is also produced by the addition of a little more lead to the flux than is used for carmine and rose colour.

The carmine colour is also produced by means of oxyd of gold, produced by the slow decomposition of fulminating gold, and a small portion of leaf silver, or muriat of silver. The preparations of gold are chiefly confined to the manufacture of what is called tender or soft porcelain, for producing carmine, purple, and rose colours. When employed for the hard porcelain, such as that of Dresden and the French, the colours are very apt to change, from the great heat employed to bake them, and in consequence they have almost entirely ceased to be used in those manufactories.

Iron Colours.—Iron is capable of producing a variety of colours on porcelain, but it is the most celebrated for producing red and rose colour. For the latter colours it is used in the state of pure oxyd, which should be of the same colour before and after baking. It is commonly prepared for the common pottery by calcining green vitriol at a red heat, in which state it is called *colcothar* and *crocus martis*.

For the delicate colours of porcelain, it is common to prepare it with nitric acid. For this purpose, dissolve the purest iron in strong nitric acid. This acid oxydates the iron to its maximum. Let the solution be diluted, and stand till it is perfectly clear; then add a solution of carbonat of potash, till the whole of the oxyd of iron is precipitated. Wash the precipitate well with hot water. Drive off the last washing by heat, and raise the heat almost to redness: this will drive off the carbonic acid. This oxyd will now be of a fine red colour, and is fit for use. A certain portion is now mixed, and intimately ground with the flux, which is then laid on with the oil of turpentine, similar to the gold colour.

This colour is employed with great success in painting

hard porcelain for the rose and red colours, and is much preferred to gold. On the contrary, the iron colour does not answer so well for the soft porcelain, as it becomes very faint by baking, and sometimes almost disappears when the heat is great. It may appear a paradox that the iron should answer for hard porcelain, which is baked at a much greater heat than the soft; while it should totally fail with the soft, if the heat be much increased above its common heat. This fact is explained, by attributing the faintness of the colour to the softness of the under-glaze of the soft porcelain, which absorbs the colouring matter; while the hard and less fusible glaze of the hard porcelain, which is mostly feldspar, has no such effect upon the colour. The oxyd of lead, which is generally present in the flux, may also have a tendency to lessen the intensity of the colour of the iron.

Oxyd of lead, as a colour, is generally used in the state of minium (red oxyd of lead) and litharge. It is reduced to a very fine powder, and washed very clean. It is often used with oxyd of tin and flint, and sometimes potash. Its general effect, when in sufficient quantity, is to produce a yellow colour. The lead, being in small quantity, and mixed with a certain portion of oxyd of manganese, has no colour. The oxyd of lead alone fuses into a transparent glass of a beautiful yellow colour.

Oxyd of antimony is employed to give a yellow colour to porcelain. The oxyd is prepared by dissolving antimony in the state of regulus in muriatic acid, with heat, and to the clear solution add water, till no more precipitation takes place. Separate the white powder, and add to it a solution of carbonat of potash to take up the remaining acid. The white powder, well washed with hot water, and dried, will be the pure oxyd of antimony. This oxyd may be fused into a yellowish vitreous mass. If it be exposed to heat for some time, it absorbs more oxygen from the atmosphere, and becomes volatile. This oxyd, with its proper flux, which may be similar to that used for the other oxyds, produces a yellow colour. It is generally used with lead, and sometimes also tin for this colour.

Oxyd of cobalt is almost the only substance used for giving a blue colour. Its being used with so much certainty, as well as its superb colour, renders it of great importance in manufactures of porcelain and pottery. To prepare oxyd of cobalt, let the arsenical ore of pyrites be treated with nitric acid. Most of the sulphur is separated in its pure form, but some becomes converted into sulphuric acid. The latter, with the arsenic acid, formed at the expense of the nitric acid, is to be separated by the nitrat of lead, adding the latter so long as any precipitate is formed, but not more. If an excess has been added, the lead may be separated by sulphuric acid. If copper be present, separate it by a bar of iron. Precipitate the oxyd of cobalt, held in solution by carbonat of potash. If the precipitate be digested in liquid ammonia, the oxyd of cobalt and nickel, if any, will dissolve, while the others will remain. Drive off the ammonia, and add a solution of pure potash: the pure oxyd of cobalt will dissolve, leaving the nickel behind. The pure oxyd may be separated by adding an acid. This last process is to be pursued only when it is required to get the oxyd in a state of purity. The common process is to roast the ore above-mentioned, by which the arsenic and sulphur are expelled. The residuum consists of the oxyd, contaminated with a little iron, nickel, and copper, and with silica. In this state it is sold under the name of *zaffer*. This mass admits of fusion into a blue vitreous mass, which is called *smalt*. In the two latter states it is used in the colouring of common pottery. We have already observed that oxyd of cobalt, when used for the blue colour, is in general

laid on before the glazing. This is more particularly the case when the deep blue ground in porcelain is to be formed. The greater the heat, the more intense and fine this colour becomes. Hence the blue is much better upon hard than soft porcelain. When great heat is given to it, the oxyd becomes, in some measure, volatile, since the white ground in its vicinity becomes a little tinged with its colour. The oxyd of copper has hitherto been employed for producing a green colour. There are two oxyds of this metal, one the brown or protoxyd, the other the black, containing a maximum of oxygen. The former produces a reddish-brown, the latter the green colour. The brown oxyd is generally obtained from the surface of copper by the action of heat. The brown scales which are detached from the surface are made into a fine powder. The black oxyd is best obtained by first precipitating the oxyd from a nitric solution of copper by lime water. Let the precipitate be dissolved in ammonia; then draw off the ammonia by distillation, and the black oxyd will be left in the residuum.

The brown oxyd, being melted with its flux, produces a reddish-brown glass. This, being pounded, may be used with other colours for producing the different tints of red and brown. The black oxyd, treated in the same way, produces a green colour. The oxyd of nickel has been tried in painting on enamel and porcelain, and is said to produce a green colour. The oxyd is obtained from the ore by the same method given for obtaining oxyd of cobalt. The ammoniacal solution spoken of in that process, generally contains both those metals. The residuum which the solution of potash leaves, is oxyd of nickel.

The oxyd of chrome has been tried in the manufactory at Seve by Brougniart. With the chromate of lead he produced a blue of considerable beauty. This substance is found in nature, and might be employed to advantage.

The oxyds of tin and arsenic do not produce any colours, but have the property of producing opacity when united with transparent vitreous bodies. The former, it may be remembered, is in the composition of the white enamel before-mentioned, to which it owes its milky and opal appearance. Arsenic has the same property to a certain extent. The latter, however, may be united with glass, without diminishing its transparency. The mass, when fused, becomes transparent; but when it is exposed at a red heat to the air for some time, it assumes an opaque and opal appearance. Arsenic is very seldom used in enamels, the oxyd of tin answering the same purpose: this circumstance, and also the danger in preparing arsenic, are sufficient reasons for laying it aside. With these metallic oxyds, separately or combined, all the varieties of tints which can be produced in the common methods of painting are obtained.

These may be divided into blue, purple, violet, red, rose colour, carmine, brown, orange, and yellow.

The blue is produced to the greatest advantage by the oxyd of cobalt. Its flux for soft porcelains is potash, silica, and lead; that for hard porcelain being felspar alone. The flux recommended by Chaptal, already given, would answer for the soft porcelain. In some instances it might be proper to use lead instead of borax. When lead is used, the coloured coating is less liable to crack and peel off. When borax or potash is used in sufficient quantity, the lead may be omitted.

The purple is produced on soft porcelain by the purple powder of Cassius, the flux containing a greater proportion of lead, in the absence of which the colour would incline to red. Oxyd of manganese, which is found plentifully in nature, and used for bleaching, produces a purple colour, but it is seldom used for that purpose. The

purple tint may also be produced by the mixture of red oxyd of iron with cobalt. These may also give the different states of indigo and violet.

The reds are produced in soft porcelain by a compound of one part of the purple powder of Cassius, and five or six of the flux with borax. This red, with particular management, may be varied from a carmine to the rose colour. These colours may be much modified by the use of a little leaf silver, or muriat of silver ground up with the flux. The reds of hard porcelain are produced with good effect from the red oxyd of iron. If this oxyd be mixed with an oxyd of the same metal having less oxygen, a great variety of tints may be produced from orange and carmine to purple. Indeed it may be possible to produce every possible colour with iron in different degrees of oxydation. Manganese may be employed with iron to afford a variety of tints.

Browns are produced in soft porcelain by the brown oxyd of copper, with manganese and the brown oxyd of iron. By varying the proportions of these, different shades of brown are obtained.

Orange and yellow are produced by the oxyds of lead and antimony, and different proportions of red oxyd of iron give various tints of orange. The antimony and lead produce yellows of different degrees of intensity, according to the quantity employed. Great care is required in the management of the heat; if the heat be too great, the oxygen leaves the lead and forms black spots.

In all instances the colour is to be mixed with the flux, and sometimes fused with it, and afterwards reduced to powder. This is more especially the case when oxyd of copper is employed. The powder is ground with oil of turpentine rather in a vitid state: with this substance the articles are painted. After painting they require to be baked or fired, for the purpose of fusing the matter laid on. This is not only necessary to fix it, but in most instances the colour does not appear till it becomes fused with its flux. The baking is performed in furnaces, called enamel kilns. The enameller, who has the same work to perform, uses a muffle. But in baking porcelain the furnace employed is generally made of cast iron. It consists of a cubical vessel provided with a lid: four sides are surrounded by a loose wall of brick, perforated with holes. The space between the two vessels is about four or five inches: this cavity is filled with charcoal. The outer casing is deeper than the inner, that the top may be covered with charcoal. The holes in the outer casing are to admit air for the combustion of the charcoal.

The ware is piled up in the enamel kiln on iron grates, resting on earthen props of different lengths, forming alternate strata with the grates, and the lid placed upon it. The charcoal is now set on fire at the top, and kept up till the colour is brought out. For the purpose of ascertaining when the proper effect is produced, there is an opening from the side by a tube which passes from the outer casing to the inner vessel. Small specimens are passed through this tube, having the different colours painted upon them. The tube is stopped with a plug. These specimens are withdrawn from time to time with a pair of small tongs, in order to know when the fire is to be removed. The whole is now left to cool before the porcelain is taken out.

It will be obvious, that when one colour requires to be laid upon another, this is performed by a second operation. It frequently happens that a piece of porcelain has to go into the enamel kiln four or five times, when a great variety of colours is contained in the painting.

Besides the painting, porcelain is frequently ornamented by gilding. This is performed in a manner very similar to the painting. The precipitate of gold from its solution is ground up with the oil of turpentine, and a very small quantity of the flux. The parts intended to be gilt are covered with this, similar to the painting, and are fired in the same way. The oxyd of gold, in this case, is not defended by the flux, and the oxygen flies off, leaving the gold in its metallic form, firmly fixed to the porcelain. The gold, although metallic, is dead in its appearance, and requires to be burnished. This is another department in the manufacture of porcelain. The burnishers are of hardened steel polished, and the blood stone, and are used in the same way as in burnishing gold and silver vessels. The common kinds of porcelain are painted by means of copper-plate prints. This, however, is more practised in the manufactories of the common earthen-ware. See POTTERY.

PORCELAIN Earth, or Clay, (Kaolin,) in *Mineralogy*, is referred by Kirwan to the second tribe of argillaceous earths.

Colour, white, greyish-white, or reddish, or yellowish-white.

Lustre, o. Transparency, o.

Friable and dusty, often compact.

Adheres very slightly to the tongue.

Feels soft but not greasy.

Hardness seldom exceeds 4; but lately some much harder has been found in Siberia Maquart 430. Sp. gr. (which is best taken when hardened by fire) varies with the proportion of its ingredients between 2.23 and 2.4. That of Limoges, which is worked without any mixture, has its spec.

gr. 2.341. Brillon 273.

In water it immediately falls into powder. Those of Japan, and St. Irie in France, are perfectly white; those of Saxony, reddish or yellowish; those of China, and Cornwall, are mixed with particles of talc and mica.

In general porcelain earth is infusible in our furnaces, as Cronstedt remarked; but, in manufacturing this earth, some fusible ingredient is commonly added; however, nature sometimes furnishes these ingredients with the earth, and to this compound we cannot refuse the name of porcelain earth. According to Mr. Hassenfratz, to whom mineralogy, in all its branches, and the arts connected with it, are much indebted, the porcelain earth of Limoges above mentioned contains, when dried, 0.62 filex, 0.19 argill, 0.12 magnesia, and 0.07 baroselenite. Mr. Wedgwood, in the porcelain clay of Cornwall, found on the contrary 60 per ct. argill, and only 20 of filex; this clay is therefore infusible. When dried by a summer heat, or that of a room moderately warm, it loses about $\frac{1}{10}$ of its weight; in the heat of boiling water as much more; in that of melted lead, and thence to a strong red heat, in which copper melts $\frac{1}{10}$, in all $\frac{1}{10}$; after that no more. The matter thus lost is common and fixed air, but no inflammable air. Hence it appears to differ from the first tribe, or native argill, only in containing filex. It has been suggested, that porcelain clays derive their most estimable properties from a mixture of magnesia. Mr. Nicholson, in his Journal, vol. xii, mentions a porcelain earth, which appeared, upon analysis, to consist only of carbonate of magnesia and filex. Magnesia is said to be of use in porcelain, by diminishing the degree of contraction to which it is liable.

Porter

PORTER, a malt liquor, which is a favourite beverage of the inhabitants of London, and other large towns. The distinguishing characters of this liquor are its deep brown colour, and an agreeable flavour, which it is difficult to de-

scribe, our language having so few words expressive of different tastes. The origin of the name is thus related by the ingenious editor of the *Picture of London*. "Before the year 1730, the malt liquors in general use in London were ale, beer, and two-penny, and it was customary for the drinkers of malt liquor to call for a pint, or tankard, of half and half, *i. e.* a half of ale and half of beer, a half of ale and half of two-penny, or half of beer and half of two-penny. In course of time it also became the practice to call for a pint or tankard of *three-threads*, meaning a third of ale, beer, and two-penny; and thus the publican had the trouble to go to three casks, and turn three cocks, for a pint of liquor. To avoid this inconvenience and waste, a brewer of the name of Harwood conceived the idea of making a liquor, which should partake of the same united flavours of ale, beer, and two-penny; he did so, and succeeded, calling it *entire*, or entire butt, meaning that it was drawn entirely from one cask, or butt; and as it was a very hearty and nourishing liquor, it was very suitable for porters and other working people; hence it obtained the name of porter." The house of Harwood is still a respectable brewery; but an immense trade has, since the period above-mentioned, arisen, and is divided among several brewers.

At first, the only essential difference in the methods of brewing porter and other kinds of beer, was, that it was brewed from brown malt, and this gave to it both the colour and flavour required. Of late years it has been brewed from mixtures of pale and brown malt, and the colour of the present liquor is much less than was formerly esteemed requisite: but finding that pale malt yields a much greater portion of saccharine matter than brown, the greatest number of the London brewers have given up the brown malt altogether, using pale and amber malt, which is intermediate between the two. From these they procure a liquor of proper strength, and they give it both colour and flavour, by the addition of colouring matter made from burnt sugar, or by burning the sugar of concentrated wort. All the London porter is professed to be entire butt, as indeed it was at first; but the system is now altered, and it is very generally compounded of two kinds, or rather the same liquor in two different stages, the due admixture of which is palatable, though neither is good alone. One is mild, and the other stale porter; the former is that which has a slightly bitter flavour, from having been lately brewed; the latter has been kept longer. This mixture the publican adapts to the palates of his several customers, and effects the mixture very readily, by means of a machine containing small pumps worked by handles. In these are four pumps, but only three spouts, because two of the pumps throw out at the same spout: one of these two pumps draws the mild, and the other the stale porter, from the casks down in the cellar, and the publican, by dexterously changing his hold to the handle of the next pump, works either pump, and draws both kinds of beer at the same spout. An indifferent observer supposes, that since it all comes from one spout, it is entire butt beer, as the publican professes over his door, and which vulgar prejudice has decided to be the only good porter, though the difference is not easily distinguished.

By referring to the article **BREWING**, our readers will obtain correct ideas of the general principles of the art, and under the present we propose to detail the process of brewing porter; and also to describe the utensils and machines used by the London brewers, who, in consequence of the very large scale on which they conduct their processes, have been induced to study, with the most minute attention, every

thing which can tend to improve their beer, or economize the materials; as also to diminish the labour of removing such large quantities of liquor from one part of the works to another: in this their grand agent is the steam-engine, which gives motion to several very capital machines.

There are in London twelve houses, which are considered as the principal porter-breweries, and from the returns of the excise, we find that the quantities of beer they brewed in the course of two years, *viz.* from July 1810 to July 1812, was as follows.

	Barrels in 1810 and 11.	Barrels in 1811 and 12.
Barclay and Perkins, Borough	264,405	270,259
Meux, Reid, and Co., Liquor-pond- street	220,094	188,078
Truman, Hanbury, and Co., Brick- lane	142,179	150,164
Whitbread and Co., Chiswell-street	122,316	122,446
Calvert and Co., Thames-street	105,887	108,212
H. Meux and Co., Marlborough- street	103,152	102,403
Combe and Co.	81,761	100,824
Brown, Parry, and Co., Golden-lane	72,367	—
Goodwynne and Co., Wapping	85,181	81,022
Elliott and Co., Pimlico	58,042	58,385
Cocks and Campbell	—	51,474
Taylor	46,222	51,220
Clowes, Maddox, and Newbury, Tooley-street	36,872	34,010

Of these works, the first that had a steam-engine, and the most complete in its arrangement of the utensils, is Mr. Whitbread's in Chiswell-street. This gentleman having permitted our draughtsman to take drawings from the most interesting parts of his extensive works, we shall proceed to explain them, with the assistance of *Plate Porter Brewery. Figs. 1. and 2.* of this plate are elevations of the whole brewery, being intended to shew the connection of all the parts at one view; but we must premise, that these elevations are in a great degree imaginary, and are not to be considered as taken upon any particular planes, because the different erections would then fall one behind the other, so as to hide them from the view; they are therefore represented in such situations as would be most convenient for explanation; but the relative levels, as also the dimensions of the individual vessels, are correct. A A, (*fig. 1.*) is the building containing the steam-engine, which is of twenty horses power, and gives motion to all the machines by a wheel on the axis of the fly-wheel, turning another upon the horizontal shaft, and this leads to the mill, where it turns the great horse-wheel B B. This wheel drives several other wheels, to convey the power in different directions. It was the original first mover of the mill; and when, (by the invention of Mr. Watt,) the steam-engine was rendered applicable to turn machinery, the horse-wheel was very judiciously retained, as by this means, if the engine should break, or be disabled, during the process of a day's brewing, the work can be continued by putting the horses to the wheel. This is a great advantage, because the delay of a few hours in pumping up the beer, in more than one of the stages, would certainly produce a premature fermentation, and spoil the whole quantity. The water for the brewery is raised from a deep well by a pump placed in it, and this is worked by cranks and rods, *b*, from the beam of the engine. The well is situated out in the yard, and the cranks are placed in an arched passage, which leads from the engine-house to the well. The

pump, by means of a pipe *d*, forces the water up to an immense reservoir, called the *liquor back*, placed at a sufficient elevation to supply the whole brewery. In *fig. 1*. this reservoir is represented as placed over the steam-engine, which indeed is its usual position in the large London breweries, but in Mr. Whitbread's it is erected over some buildings which could not be shewn in our plate: from this the reservoir pipes are laid, to convey the water to any part of the works where it may be required. The principal of these are to the coppers B, of which there are three, placed close together, but only one can be seen. C is the chimney for it, and the same roof, D, covers them all. The water, being heated in the coppers, is conducted by a pipe, *e*, to the mash tuns E: one of these is placed immediately before each of the coppers, though only one is to be seen in the view. During the process of mashing, the malt is kept constantly stirred by machines in each tun, which receive their motion from the steam-engine by the shaft *f*: this passes over the centre of all three, and by means of bevelled wheels, gives motion to a vertical axis in the centre of each tun, which are the principal axes of the machines. The malt, previous to mashing, is ground, or crushed, to render the husks pervious to the water. In most breweries it is ground between mill-stones, such as are used for grinding corn, but in these works it is broken between iron rollers, *g, g*, similar to those used for flattening iron: they are 18 inches in diameter, and two feet six inches in length, and are situated at such a distance asunder, that only a piece of thick brown paper can be passed between them; they are turned by wheels from the long horizontal shaft *a*, and immediately above them is a third roller, which has a number of deep flutes, or cavities, cut in it, from one end to the other, and these, as it revolves, become filled with malt from the hopper above, and then deliver it to the two rollers, which, being in motion, take it between them, and crush all the grains flat. By this, which is called a feeding roller, the supply to the rollers is kept constant and regular, without which they would be in great danger of clogging up, or setting fast. The malt, when it has passed through the rollers, is completely broken, even its most minute grains, but very little of it is cut into flour; for the husks of the malt, though cracked so as to admit the water readily to the contents, still prevent the flour being separated. This is a great advantage over the method of grinding, because that produces a great quantity of flour, which is the richest part of the malt, but when it is ground fine, and separated from the grain, it does not yield so much extract in the mash tun, as when it is preserved in the grain, and the husk sufficiently broken. This is because the flour, when immersed in the water, and wetted, forms a sort of paste, which at first absorbs a considerable portion of water, but will not afterwards quit it, so that very little extract is obtained from that portion of the malt which is separated from the grain, in the state of flour. The store of malt, before it is ground, is kept in the malt lofts over the mill, as represented. When it is brought in waggons to the yard, close by the mill, the sacks are drawn up by the tackle at F into the loft, and here the sacks are shot down, through holes in the floor, into the great store malt lofts, and from these, as it is wanted, is drawn out, through shuttles, into the hoppers of the rollers *g, g*. The store lofts extend much farther than we have been able to represent them in *fig. 1*, but may easily be imagined, as they are only a repetition of eight or ten of those shewn in the figure, the same loft extending over the whole, and the same sack tackle drawing up the sacks from the carts in the yard; though this, of course, is not situated at the end of the mill over the pumps, but at the side, where it could not have been seen. The malt, after passing through the rollers *g, g*, descends into

a chest, whence it is conveyed to the malt bins over the mash tuns E, by the motion of an inclined screw *b*: this is a wooden trunk or trough, in which the screw is fitted to revolve, and thus gradually pushes or raises the malt which is contained in the trough, from the lower end of it to the upper, which, being within the malt bin, and at the farther end of it, the screw completely fills, by distributing the ground malt at all parts of its length. The screw itself is formed of thin iron plates, bent into a screw, and fattened, by nails, to a central wooden axis, which revolves by the mill. When the malt is wanted for mashing, it is let down from the bin into the mash tuns, through sluices, or shuttles, in the bottom of it, and curtains are hung up all round from the bin to the edge of the tun, to prevent loss from the dust or flour of the malt flying in the air. After the process of mashing has continued a sufficient time, the extract or wort is drawn off from the mash tuns into other tuns, G, beneath, which are called the under-backs; here it remains only till the coppers are ready to receive it; and it is thrown up by the pump, H, into the copper-back I. This is a shallow cistern placed above the coppers, and from it the wort can be admitted into any of the coppers, or into their pans: these are vessels which are placed over the coppers, and their contents receive heat from the steam raised by the boiling of the copper itself.

To understand this see *fig. 3*, which is a section taken through the centre of the copper. AA is the fire-grate, B B C the copper itself, containing 350 barrels; its top is a dome, and has a cylinder, G, rising up from it: FF is the pan, erected upon the top of the copper, and enclosing the dome C, within. The pan contains 250 barrels of liquor, which is heated by the steam rising into the cylinder G, and thence descending by pipes *d, d*, down into the liquor, and bubbling up through it. The heat communicated through the dome also assists in heating the contents of the pan. There are two valves in the head G, which are kept shut by staybolts and weights; but these being opened, the steam of the copper is allowed to escape through a copper pipe or chimney, K, (*fig. 1*.) into the open air. E (*fig. 3*.) is an iron door, to allow entrance, into the copper, and also to put in the hops; it is situated on the top of a cylinder rising from the dome, and is fitted so closely by grinding, that it is steam-tight when shut, and forced down upon its seat by a screw. Two flues proceed from the fire-grate at the farther end, and conduct the flame and heated air round in opposite directions, as shewn at D D, to the chimney, which is placed over the fire doors, and thus the heat is applied to the sides, as well as to the bottom of the coppers: this, as the figure shews, is made concave beneath, to allow a greater action to the fire. The chimney is open at the bottom, and, therefore, the draught it occasions through the flues is only by the lateral action of the current of air, occasioned by the column of rarefied air in the chimney; but this draught can be cut off, when it is required to damp the fire, by shutting up two iron doors at the ends of the flues, and then no air can pass through the fire. In some breweries, doors are provided to shut up the bottom of the chimnies, and thus increase the draught, by compelling all the air which enters the chimney to pass through the fire-grate, and thence by the flues into the chimney; this causes the copper to boil much quicker, but the violent heat soon destroys the copper at the bottom, by burning or melting it. When the hops are boiled in the copper, they are kept in constant motion, to prevent their lying upon the bottom and burning to it. This is done by a machine called the *rowser*, contained within the copper; it consists of a vertical spindle, *e*, in the centre of the copper, which at its lower extremity has a cross arm, *g*, curved, to correspond with the bottom, and

from this a number of loops of heavy chain are suspended, to drag round upon the copper when the spindle is turned, and by this means the hops are raked over and continually disturbed. The spindle passes through a stuffing-box in the centre of the top, *G*, of the copper, and is turned round by a wheel *f*, engaged with another upon a shaft receiving motion from the engine. The direction of this shaft is shewn dotted in *fig. 1*, at *x*, but is there vastly extended in length, as is also the screw for the malt, because the engine and mill in reality stand in the line of the house containing the coppers and mash tuns, and at the end of them, in which position it would have been hidden by the building. The same shaft, *x*, also gives motion to the hop tackle, for drawing the hops up to the top of the copper, where they are thrown in at the door of it, *E*, *fig. 3*. The rowler can be drawn up from the bottom of the copper when it requires to be cleaned, for which purpose its spindle is suspended by a sort of tackle, that will quickly raise it up six or seven feet. The copper is provided with a float, to shew the height of the liquor within it: this consists of a strong wire, passing down through a tight stuffing-box in the top of the copper, and suspending a stone at the lower end of it: from the upper end of the wire a line is conducted over pulleys, which has a ruler or rod divided into feet and inches suspended from it, with a weight greater than the weight of stone when it is suspended in the liquor, but less than the weight of the stone when it is drawn up out of the liquor. In this situation the stone will always be at the surface of the water, in the same manner as if it floated, and will shew the height of the liquor in the copper. There are several pipes and cocks belonging to the copper, which are as follows: a pipe leading from the liquor back to introduce water into it; this has a cock formed of two passages, one admitting it to flow into the pan, and the other conveying it by a short pipe into the copper itself, and the handle being turned in one direction or the other, shews which way it will run, or turned in another direction it stops up the pipe; there is also a hole in the bottom of the copper back, through which the contents run down into the pan, but can be closed by a plug, and near it is a pipe leading down through the pan into the copper; this is closed by a valve, which can be opened by a lever and screw, when it is required to convey the wort from the copper-back into the copper itself; there is also a valve, which communicates at once from the pan down into the copper. From the bottom of the copper is a large cock with a pipe *c*, which runs horizontally over all the three mash tuns, and at every one a branch descends beneath the bottom of the tun, and turns up, with two or three smaller branches, leading into different parts of the bottom, by which means the hot liquor is admitted from the copper into the tun; it enters in different places at the same time, a precaution which is very necessary to distribute it equally through the whole of the malt in a tun, which like this is twenty feet in diameter; but to do this more effectually, the tun has a false bottom perforated with small holes; upon this the malt lies, and the water, being introduced beneath it, flows upwards through the holes in all parts at once.

The mashing machine, (see an elevation of it in *figs. 4*, and *5*.) is composed of several endless chains, *R*, extended over two wheels in the manner of chain pumps, and the links of the chains have rakes, *d*, fixed upon them, and as the wheels revolve, ascend and descend through the whole depth of malt contained in the tun, and thus effectually stir up the whole to incorporate it with the water. That this action may be performed in all the parts of the tun, the frame containing the wheels and chains is adapted to have a progressive motion round in the tun, by turning round upon the vertical axis, *D*, in the centre. This axis has a bevelled wheel, *E*, upon it,

which turns another upon the end of a horizontal shaft *F*, carrying the wheels, *e*, for the chains *R*, and extending from the centre of the tun to its circumference, that end being supported in a frame *S*, which rests with wheels upon the rim or edge, *T*, of the tun: the interior end is sustained by a frame *S*, (*fig. 5*.) fitted upon the vertical axis, *D*. Near the bottom of the tun another horizontal shaft, *V*, parallel to the former, is placed, and has upon it the lower wheels, *e*, for the endless chains of rakes. The pivots of this shaft are supported in the same frame *S*, as the upper: this being, as before mentioned, fitted upon the central axis, *D*, at one end, and the other end resting with wheels upon the edge, *T*, of the tun, it may be made to traverse round the tun. This is done by having a ring of cogs fixed upon the edge of the tun at *T*; and an endless screw, which is supported on the frame *S*, engages the teeth. By means of bevelled wheels, *l*, this screw is turned slowly round from the upper axis, *F*, of the chain wheels; and it can, by means of a small handle, be disengaged from the motion, or it can at pleasure be engaged with either of two different pairs of the bevelled wheels, one giving it a slow motion and the other a much quicker; the first being used to traverse the machine round the tun till the malt is completely wetted, and then the quicker motion is used to mash the malt up thoroughly. This machine is the invention of Mr. Cooper, who had a patent for it, and has made great numbers. Several other ingenious machines have been invented, but are not yet in general use; one by Mr. Sylvester, another a patent by Mr. W. Jones; (see Repertory of Arts, first series, vol. ix.); a very simple one by Mr. Goodwynne, which he employs in his own brewery; a fifth kind of machine is described in our article BREWING. Mr. Jonathan Dickson has a patent for a method of making mash tuns in cast iron, by which the very heavy expences of constantly repairing, and often renewing, wooden vessels is reduced to a trifle. Messrs. Barclay and Perkins have one of these in use at their brewery. The mash tuns at Mr. Whitbread's brewery are lined with thin sheet copper, applied in the same manner as the sheathing of a ship, to prevent leakage, and keep the vessel sweet and clean. The mash tuns are supported upon a framing of timber, as shewn in *fig. 1*, which leave room within them for the under-back *G*. The malt-bins are supported over them by an assemblage of pillars between each of the tuns; and to give greater strength to the horizontal beams *1*, which are beneath the bins, other horizontal beams, *2*, are placed at a considerable height above them, and the two pairs being connected by framing and oblique braces, they form a truss frame similar to a roof, which will bear the weight of the bin, when full, without sinking. The pipe *3*, which draws off the wort from the under-back, is conducted to the three-barrelled pump at *H*, which is worked by the mill: this elevates it to a trough, which extends over the whole length of the copper-back *I*, and by means of a plug in the bottom the wort can be let down into it.

When the wort has been boiled in the copper with the hops, both together are run off, at *k*, into the jack-back *M*: this is in reality a large strainer, to separate and retain the hops. It is a very large back, provided with a false bottom, composed of cast-iron plates pierced with small holes. Through these the liquor drains, when the pipe, *l*, from the bottom of the back is opened, and the hops are left upon the false bottom: the pipe, *l*, is conducted to the pump at *H*, and this raises the wort up to the same trough, over the copper-backs *I*; but instead of being run into these it is conveyed forwards, by a succession of troughs, and distributed into the different coolers *N, N*. These are large backs, and very shallow, several being placed in succession over each other, and the windows of the building are made very open,

to admit a current of cold air, to carry the heat off from the beer. In these it remains a sufficient time, till it is cooled to the temperature desired, and then it is drawn off from the coolers into the fermenting house. This is a very large building, placed adjacent to the engine-house. A section of it is given in *fig. 2*: here *p* is the copper pipe, proceeding from the coolers (having numerous branches to all of them), to the gyle-tuns, or squares *P*, which are large open vats, of sufficient capacity to contain the beer of a whole brewing; here yeast is put to it, and the fermentation commences, and having continued a sufficient time, the beer is distributed into the small tuns, *Q*, called rounds, where the fermentation is concluded, and the yeast, as fast as it is produced, flows over by a spout into the troughs *m*, which are placed between every two rows: this cleanses the beer, by the separation of the yeast from it; and as by the division into small quantities, (for the rounds only contain nine barrels each,) the temperature is lowered, and as the disposition to fermentation gradually subsides, the beer becomes fit for storing in the vaults or under-ground cisterns *T*, that it may be kept, till by age it becomes fine and fit for the table. The squares *P*, (for there are two, one behind the other,) are 22 feet by 24, and 9 feet deep, so that their content is nearly 800 barrels each. The pipe *p*, from the coolers *N*, (*fig. 1*.) has a branch proceeding to each square, and a double-passaged cock, 4, which will admit it into either, according as the handle is turned to one or the other. The pipe itself proceeds in an inclined direction to the bottom of the square, as shewn by the dotted lines, and thus introduces the beer in the centre, by which means, if there is any variation of temperature in the contents of the square, and that which has recently entered, it will sooner be brought to an equality.

Mr. Richardson, who conducts the brewing at Mr. Whitbread's works, has made an arrangement which deserves particular notice, and is worthy of imitation by other brewers. The pipe, *p*, is made of thin copper, and is enclosed within another pipe, the space between them being supplied with a stream of cold water. To effect this, the main ascending pipe, from the well to the liquor cistern, is not in reality carried up direct, as shewn by *d*, in *fig. 1*, but is placed in the angle of the fermenting house at *d d*, *fig. 2*. A branch, 5, proceeds along the wall thereof, then makes a turn, and joins the external pipe *p*: from the other end of this a branch is conducted to return the water to the main ascending pipe *d*, and in this there is a cock between the two branches, and another upon the branch: now the latter being shut, and the former open, the water ascends at once up the pipe from the well to the reservoir; but when the beer is to be drawn off from the coolers into the squares, the cock in the main pipe, *d*, is shut, and the other opened, by which means all the cold water which the pump throws up from the well is forced through the space surrounding the pipe *p*, in which the beer flows, and thus cools it very effectually. To determine the temperature, the bulb of a thermometer is placed in the centre of the pipe, and its tube comes up through it at 6; then a man is stationed to watch this, and when he observes it sink to the degree at which it is determined that the beer shall be left to ferment, he opens the cock and permits the beer to flow into the square; but still continues to observe the thermometer, and if it sinks lower he opens the cock wider, to admit the beer to flow quicker through the pipe *p*, that it may not be so much cooled by the flow of the cold water; or, if this is not sufficient, he regulates the quantity of cold water, by means of the cocks in the main pipe and the branch: on the other hand, if the thermometer indicates that the beer is not sufficiently cooled,

the cock is closed a little; this retards the passage through the pipe, and lowers the temperature, by subjecting it for a longer time to the action of the cold water. By this simple contrivance, the brewer is at a certainty that his liquor has been put to ferment in the square or gyle-tun *P*, at the exact heat which he intended, a circumstance which was before very uncertain; because, being drawn from so many different coolers, some would of course be less cooled than others, from their different situations, and it could only be guessed what temperature all these different degrees of heat would make when mixed together in the square, and the larger the scale of operation, the more uncertainty; because such large bodies of liquor take a considerable time to flow, and by passing such great lengths of pipes generally lose some heat; but it cannot be guessed how much. In Mr. Richardson's method, this is accurately determined, and capable of regulation. A long thermometer is fixed in the sides of the squares, to shew the temperature of their contents, and this is found to increase during the fermentation; no yeast is removed from the beer in this stage, indeed scarcely any is formed, for though a very large white head collects upon the surface, it is only light bubbles which instantly fall by the least agitation. The fermentation in the squares is generally concluded in thirty hours, and then the beer is removed to the rounds for cleansing from the yeast. It is first run off by a pipe 7, from the squares, into the filling up vessels *R*, *R*, which are in reality placed in the space between the two squares; but could not be so represented. When these are full, the pipe is shut, and another cock, 8, opened, which permits the beer to flow through pipes 9, conducted beneath all the rounds *Q*, *Q*; and from these, cross branches are conducted between every two rows, and by short pipes introduce the beer into the casks: thus they are all filled at once, and then the cock, 8, is shut. The casks are 240 in number, being arranged in sixteen of the rows which are seen in our figure, though only eight are drawn there; and each row contains fifteen of these casks. The troughs, *m*, between each pair of rows extend the whole length to receive the yeast produced from them, which in this stage of the fermentation is caused to flow off as fast as it is produced; and by this means it is that the fermentation is allayed, because the yeast which constantly keeps it going on, is not suffered to rest upon the surface of the beer. To render this effective, the rounds have close heads, and rather inclined to one side, where is a spout to conduct the yeast into the trough, therefore this spout is at the highest part; and there is no considerable surface exposed, upon which a head of yeast can float, to keep up the fermentation. But as the rounds gradually diminish in content, they are filled up by fresh beer from the filling-up tuns *R*, which were previously filled, as a reserve for that purpose. A pipe from the bottom of these enters into a small cistern *S*, where its orifice is closed by a valve. This is opened by a wire, which is connected with a lever, and a float, which floats upon the surface of the liquor in the cistern; and this is, by means of the communicating pipes 9, kept at the same level with the surface of the beer in all the rounds; there being a free communication amongst them all. Now when, by the wasting of the yeast, the beer in the rounds sinks, the float in the cistern sinks, and opening the valve, admits a sufficiency of beer from the filling-up vessels to restore the level, and then the valve closes again. To prevent the beer in the filling-up vessels having an exposed surface, and to carry off the yeast from them as fast as it is produced, a moveable or floating head, 10, is adapted to the tun. This is a slightly concave pan, or dish, of plate iron, which has a pipe fixed perpendicularly down from the

centre of it, and passing through the bottom of the vessel, in a stuffing-box. This dith floats upon the surface of the beer in the filling-up vessel, and as it is not quite so large as the inside of the tun, the yeast runs over in this space, and, falling down the pan to the central pipe, runs through it into troughs placed beneath, which convey it, in common with the produce of all the other casks, to a tank, or receptacle, sunk in the ground. From this tank the yeast is raised by a pump into casks, in which it is sent away, for the use of bakers, distillers, and others who employ it. Whilst remaining in the tank, a considerable portion of beer, which the yeast carries over with it, drains away; and this is drawn off by a pump, which drawing from a lower level than the yeast-pump, raises the beer into a different cistern; and here it remains 48 hours, to ferment and cleanse itself. It is then pumped up into shallow settling backs, V, V, V: in the highest of these it remains some time to settle, and deposit any yeast it may contain, and is then drawn off into a second, and then to the third, by which it becomes clear, and is good strong liquor, though unpalatable; but being introduced into the square, at the same time with a succeeding brewing, it adds to its quantity, without injury of the quality. By this means, no waste takes place in any department of the work.

When the beer has been sufficiently fermented, and the flow of yeast ceases, by which the brewers say it has sufficiently purged itself, it is drawn off from the rounds, Q, to be flored. That is done either in large tuns W, or otherwise in the cisterns, or underground vaults T: the former is the general system of the London brewers; but the latter, which is only practised at Mr. Whitbread's, is undoubtedly the best method, because of the equality of temperature they preserve both in summer and winter; and their durability, compared with the wooden vats, is no small recommendation. Many breweries have wooden flore vats of immense capacity, being as much as 40 feet in diameter, and 20 feet deep. They are placed upon timbers, and supported by pillars, that small casks may be kept beneath them; and the beer can be drawn off into these, when it is to be sent away from the works. The vaults, T, T, are arched, and lined with stone, well bedded in cement, or pozzolana, and the joints very carefully made. They were built under the directions of the late Mr. Smeaton; but the Roman cement, which has been discovered since his time, would be the best material for jointing and lining them. A very superior cement of this kind, which is now manufactured in the north of Yorkshire, may be procured at Mr. Atkinson's wharf, Narrow-wall, Lambeth, and would enable brewers, who choose to adopt the cisterns, to have them made perfectly tight; whereas in these works they had at first much difficulty, from the defective nature of the cement; though they have remedied this, by employing resinous substances in the joints. Each cistern contains 4000 barrels, and the flore is thus kept without the loss of any room in the building; a great consideration in London, where the rent of premises is so high, not to mention the saving in the repairs, and renewal of the wooden vats.

Mr. Richardson has applied an useful contrivance in this brewery, for cooling the beer previous to storing it in summer time: it is done by collecting the beer from the rounds, Q, into a cistern thirty feet square, sunk in the ground, and having a copper pipe conducted round its sides, making three turns in it: through this pipe a constant stream of cold water is conducted, in the same manner as before described, and this cools the beer to as low a temperature in summer as it will naturally have in winter, and then it is not liable to any fermentation in the flore vats, which probably

takes place in a slight degree in the ordinary process, and is one reason why beer brewed in summer is seldom so fine as if brewed in winter. In this cistern the beer, being kept quiet and cool, deposits some sediment, apparently of farinaceous matter, which, if the slightest fermentation existed, would be held in the beer, and make it turbid; but here it seems to deposit more, and fine itself to a greater extent, in a very short time, than it would for a long period in the flore vats; for we should observe, that one principal object of storing the beer is, that it may by age become fine and transparent, which it does by very slowly depositing the excess of vegetable matter, at the bottom of the vat, in the form of slime: but if the slightest fermentation is excited in the vat, it is put into an agitation, which wholly suspends this deposition, as long as it lasts; hence the great advantage which the brewers have found from employing such large vats as are not liable to sudden variations of temperature; and, for the same reason, subterraneous vaults are better than either.

We have now described the whole of the brewery, excepting only the several flore-houses for the hops and coals, of which very great stores must be kept, for such extensive works: the latter are kept in the lower parts of the buildings, in the vaults or arches upon which the coppers are erected, and any other convenient part of the ground floor; and, in like manner, the hops are stowed away in large bags, in the lofts over the malt stores, or any other parts. The number of the rounds, Q, in the fermenting house is not correctly represented in the drawing, nor the extent of the flore vats W, which fall, at Mr. Whitbread's brewery, are situated in a large establishment on the opposite side of Chiswell-street.

The management of the brewing is thus conducted: A sufficiency of pale and brown malt, mixed, is broken between the rollers two or three days before it is wanted; and for this reason, the malt-bins are made large enough to contain 400 quarters of ground malt. Some kinds of malt, which, the brewers say, have too much *fin* in them, are found to improve by keeping some time before they are broken; but a few days keeping after they are broken will produce the same effect. The water is pumped up into the reservoir till it is full, and in this state the work begins, at two or three o'clock, by lighting the copper fires, and the engine fire, filling the coppers with water, and also their pans. The mashing-tuns have the required quantity of malt let down from the bin, the curtains before mentioned being hung up to prevent the dust flying. All this is done by a few men, and the liquor (water) in the coppers is heated to the proper degree, which is generally about 150° for the first mash, its quantity being proportioned to the quantity of the malt, nearly in the proportion of two barrels to the quarter. But both these circumstances vary in different breweries, and from various causes, as has been explained under BREWING; though, we should observe, that the remarks there made, refer rather to the process of brewing on a small scale, than in the large way of manufacture; and though the principles are the same, the actual heats in the large way are much lower, because the loss of heat in the process is so much less in the large vessels.

The liquor being heated is *turned on*, that is, introduced into the mashing-tun, by opening the cock, *e*, (*fig. 1.*) and admitting it to flow up through the malt, till in ten minutes time it has completely filled it: the mashing machine is now set in motion by the steam-engine, and works round the tun, with the slow motion for twenty minutes; then the quick motion is cast on for four minutes to complete the mashing; and after this it stands still for two hours to

make the extract, and settle clear. The tap or cock into the under-back is now set running to drain off the wort, and this is left open, until the water for the second mash is sufficiently heated. This is the water which was at first filled into the pan; and immediately the first liquor quitted the copper, the contents of the pan were let down into it; and having acquired some heat while in the pan, is soon sufficiently heated, perhaps to 160° , and at the rate of one barrel to the quarter, being only half the quantity of the first mash, because so much of that is left in the malt. The mashing machine is worked for this as before, but it only stands one hour instead of two, because the malt was completely saturated before: in this period the first mash is pumped up into the copper, and the hops being added to it, the boiling is begun. The under-backs being thus cleared, the second wort is run off into them, and stands to drain from the malt, till the third liquor (water) is ready: this has been heating in one of the other coppers, till it is at 180° , and is then, in its turn, let down into the mash tuns, is mashed, and stands an hour, during which the second wort is pumped up into the copper back of the second copper, ready for boiling, and is admitted into the pan, that it may gradually heat. If a fourth mash is taken, that no waste may be made, it is heated in another copper, and is not brewed that day, but is reserved for the next brewing, and is then used instead of fresh water for the first mash. Some brewers do not practise this method, because there is in warm weather some danger of a premature fermentation, called *foxing*, taking place in the wort which is kept; but in cold weather it may be safely done, and is a saving. We have now to attend to the boiling: this is continued for the first wort one hour; and the second, being in the pan, receives considerable heat by the steam rising from the copper. When sufficiently boiled, the first wort, together with the hops, is run off into the jack-back M, and hence it is pumped up to the coolers N. The first wort is placed in these coolers, which, being least exposed to the air, will cool slowest, because the object is to get all the different worts cooled by the same time, ready for fermentation. The second wort is let down into the copper the instant the first is run off; and the hops which are left in the jack-back are filled into buckets, and drawn up by the hop-tackle, to be returned into the copper, for boiling with the second wort; but as this continues for two hours, the third wort is thrown up, towards the end of the time, to the second copper, and the boiling begun; for the instant the second wort is distributed into the coolers, the hops are put to the third wort, and boiled with them for four hours. This boiling of the worts, coagulates great part of the solid matters which the wort extracted from the malt, and by thus collecting those minute particles which were before diffused so equally throughout the wort, as only to render it cloudy, into distinct fecula, they are disposed to deposit themselves in the coolers, which they do in great quantities; and it is by this process that the beer is first separated from the grossest part of the extract. The cooling is conducted as expeditiously as possible, and when sufficient, as shewn by the thermometer, all the three worts together are, as before explained, drawn off into the square P, which contains 800 barrels, which is the full quantity of a day's brewing; the yeast is here put to it, and the fermentation begins, and it is by this process the porter acquires its spirituous quality, and is rendered clearer, from the great quantity of mucilaginous matter which is thrown off in the yeast. The fermentation first shews itself, by the whole body of the liquor teeming with innumerable small bubbles rising to the surface, each enveloped in a thin film of yeast, which, as the bubbles

burst, collect into a head or froth, and float on the top of the liquor. The temperature of the fluid increases considerably, and the noise of these bubbles, rising through the fluid, causes a continual singing. Part of the bubbles burst before they arrive at the surface, and the film of yeast which envelopes them, sinks until it is borne up again by the ascending bubbles. These films form at first a white covering to the surface of the beer, which the brewers call the lamb's back, and as the process advances it becomes yellow, having the appearance of rocks; but this yeast is only a thin watery substance, which quickly melts down into a fluid. When the fermentation has advanced so far, that the head of the yeast begins to sink, it shews the process is past its greatest pitch, and the brewer must check it, or it would soon be succeeded by a second stage of fermentation, which produces vinegar. This check is given by the operation of cleansing, in which, as we have before stated, the yeast is carried off as fast as it is produced, and the fermentation gradually subsides.

To review the several processes of the brewery of porter, it should be observed, that it is required, in the mashing, to extract from the malt all the saccharum it contains; but the heat at which this must be done is also favourable for extracting a great proportion of the mucilage and glutinous parts of the malt, which must afterwards, in some degree, be separated from the wort, and the portion which is left will determine the flavour and colour of the beer. If the heat of the mashing liquor is too low, it will extract so much of these matters, that all the subsequent processes can never separate them sufficiently to make the liquor fine; and at the same time it will not extract much saccharum. But by increasing the heat, the mucilage becomes, in a measure, coagulated in the tun, and is not extracted in so great a degree, whilst the saccharum is taken up by the wort in a full proportion. On the other hand, an excessive heat carries this too far, for it makes a complete paste of the malt, by melting the gluten, and the whole resembles a hasty pudding. This disaster, which the brewer calls *setting the goods*, spoils the whole process, as a great proportion of the water becomes combined with the malt, in the state of paste, and will not run off; whilst that proportion which does remain unmixed, and can be drained out, has extracted little or nothing, either of saccharum or gluten, from the malt. This state of things takes place, in a greater or less degree, whenever the extracting heat is taken too high: the other extreme we have spoken of. Between these the brewer endeavours to keep, and by his success in this simple point, the quality and strength of his beer will be influenced most materially. No precise rules can be given for the actual heats, as they depend upon the nature of the malt, the heat used in drying it, (the brown requiring less heat than pale); the quality of the water has also its share, and the quantity of malt mashed at once, (because a great mash-tun loses less of its heat during the mashing than a smaller one); also the temperature of the atmosphere.

Having been thus necessitated to extract more of the solid matters from the malt that he wishes to retain, the brewer, in the succeeding processes, turns his attention to the most effective means of expelling the superabundant mucilage, and without losing the sugar, to leave a fine transparent and palatable liquor.

By the process of boiling, the grossest part of the mucilage extracted by the wort is coagulated, and in a manner precipitated into distinct fecula, leaving the liquor, which was before thick and muddy, comparatively clear between the flakes, which are so large as to be individually visible. The boiling also extracts the bitter of the hops, which is

necessary to make the beer keep, till it becomes fine and fit for the table; it also concentrates the wort, by evaporating a part of the water used in the mashing: on spreading the wort thin in the coolers, the fecula subsides, and is left behind.

The fermentation in the squares, P, does not expel any of the extract matter, but the chief object of it is, to convert the saccharum into alcohol or spirit, and at the same time it disposes the grosser parts to a more favourable state for the separation which takes place in the second fermentation in the rounds, and by the great quantity of yeast which is thrown off, the beer becomes finer, at the same time that the production of spirit continues, and it loses its sweet taste. When this fermentation subsides, the beer is stored, and remains quiet, the longer time the better, to become clear and transparent; but this is, provided the quantity of hops it had is sufficient to prevent its becoming sour, because the extract of the hop is inimical to fermentation, and prevents that process going on in the store vat, which, if it did, would produce vinegar. What is really intended in the store vat is, to deposit those finer particles of superabundant matter which have escaped the other processes, and the beer improves in its strength.

The porter brewed for the supply of London is kept a very short time, and therefore has a small share of hops; and as it would not have time to become fine, it is fined by a process on purpose, which, indeed, is necessary; for if the beer was kept till it became fine, it would, by the shaking of carriage, when sent from the brewery, be rendered cloudy; the beer is therefore sent away in the rough, and requires fining, which is done by the consumer putting into the cask a small quantity of fining, sent by the brewer with the porter. These finings are made of isinglass dissolved in four beer, made from the wort of the fourth mash, or four beer obtained from the waste of any of the processes. A small quantity of this fining being put into the cask, precipitates the minute feculæ to the bottom, and soon renders the liquor quite fine.

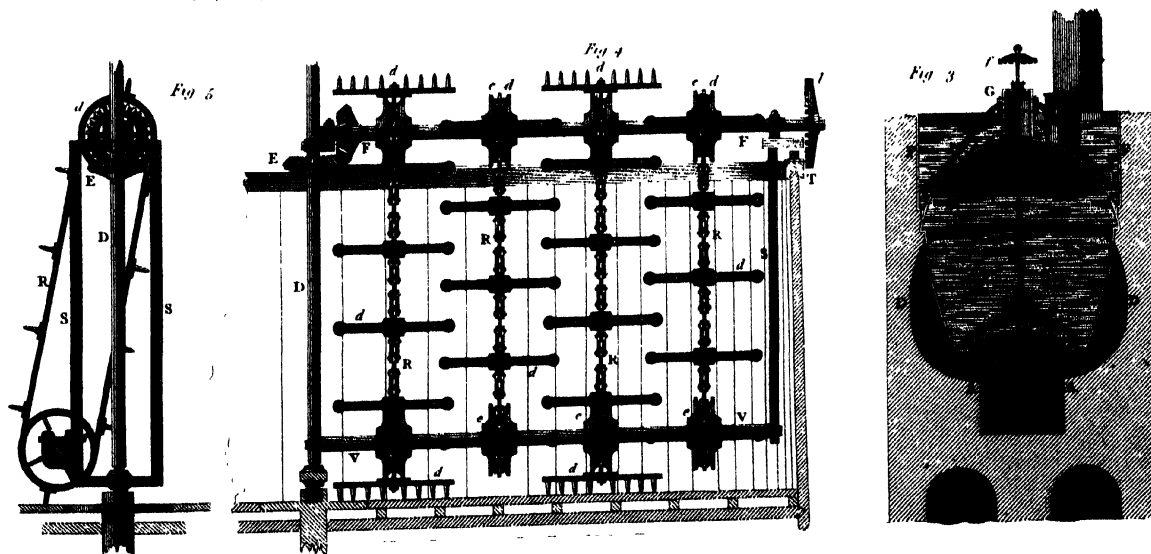
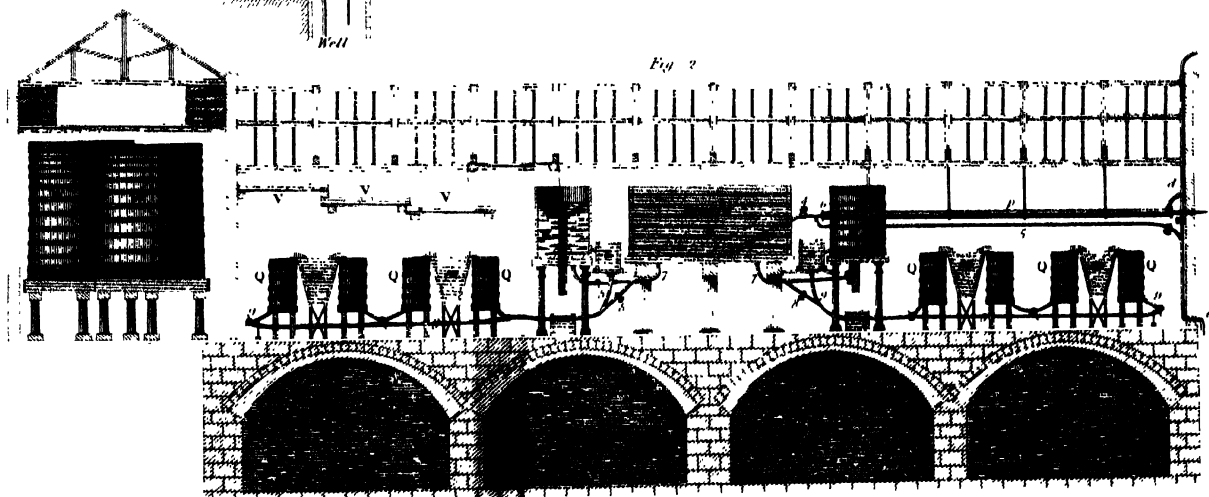
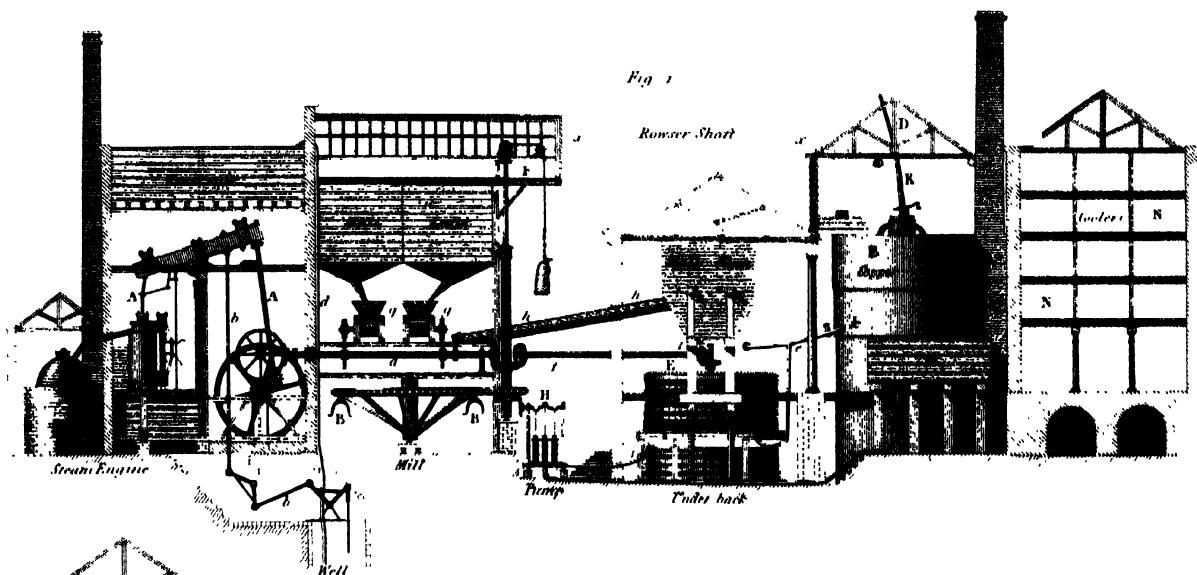
In Mr. Whitbread's works no colouring matter is em-

ployed, as he uses a portion of brown malt; but most of the other brewers use pale malt, and colour the beer, by the addition of certain colouring matter, which being obtained from burning the same substance that causes the brown colour of the highly dried malt, produces a similar liquor, at a far less expence of materials, than when brown malt alone is used; because the pale malt yields a much greater proportion of saccharine matter than the brown, in which a share of the saccharum is burnt up in the kiln, only for the purpose of producing a colour and flavour which may so easily be communicated to the beer of pale malt, by a small quantity of burnt sugar. Many brewers, to avoid the censure of the public, who require them to use malt and hops alone, concentrate a quantity of their best first wort, by boiling in an iron pan, and burn this instead of sugar, from which it does not materially differ.

The process, in either case, is to put a quantity of coarse brown sugar, (or the concentrated wort,) into an iron pan, with a small quantity of water, keeping it constantly stirred up; it is then set on fire, and burnt for a few minutes, to give it the colour and flavour which might be obtained from brown malt. The fire is extinguished by putting on a cover. The residuum is now mixed up with water to the consistency of treacle, and makes the colouring, which is put to the beer while working in the square, and gives it very near the same colour and flavour it would have derived from being brewed from brown malt.

Some of our readers may have met with pamphlets professing to describe the process of brewing porter, and mentioning a variety of ingredients, such as liquorice, essentialina, treacle, capficum, ginger, lime, coriander seeds, cocculus indicus, &c. &c., but the writer of this article, having visited nearly all the great porter breweries in London, where he has been shewn into all their store-houses, and examined every process, can safely assure our readers that no articles more than malt and hops, except the colouring and finings, are used in their works, whose beer is reputed to be the best of any, nor has he ever met with any brewer who employs such articles for brewing porter.

PORTER BREWERY



Pottery

POTTERY, the art of making earthen pots and vessels; or the manufacture of earthen-ware.

Vessels capable of holding liquid food, and drink for the use of man, would be so essential to his immediate necessities, that their fabrication would doubtless be prior to the invention of the humblest cottage. Vessels formed by excavating pieces of wood and leather, were in all probability prior to those of earthen-ware. This manufacture, however, is so ancient, that we have no traces to the period of its invention.

From the great perfection in which we find the porcelain of China, as far back as history will inform us, there is great reason to believe, that many centuries must have elapsed in bringing it to that state, could we even ascertain when it arrived at its climax. It is remarkable, that the oldest specimen of Chinese porcelain does not differ in its essential qualities from the most recently manufactured.

There is strong ground to suppose, that the art of pottery had been long brought to great perfection in the East, before it was known in Africa and Europe. It was afterwards cultivated by the Egyptians, from whom it descended to the Greeks and Romans.

A species of earthen-ware was manufactured in Persia, which was considered a great curiosity, on account of its metallic lustre. Something similar has lately been manufactured in this country, to which the metallic lustre is given by gold; and another with platina, having the colour of that metal.

The Romans appear to have cultivated this art to a considerable extent. The taste and elegance displayed in their form and ornamental decoration, were doubtless borrowed from what the Greeks had long before practised: the country most celebrated for this art was the ancient Etruria. It was the ambition of that enlightened manufacturer, the late Mr. Wedgwood, to equal the manufacture of Etruria, after which he named the village that has grown out of his genius and industry; let it, however, be said to the praise of this great man, that in his attempt to

equal the ancients, he has very far excelled any thing of the kind yet produced, in the firmness and compactness of body, in colour, and in elegance of form. It may be truly said of Mr. Wedgwood, that he has increased the value of the raw material in a greater degree than any other manufacturer. The potteries of this country, prior to his exertions and example, produced nothing but of a flimsy fabric, destitute of taste, and scarcely fit for domestic use. Their best production was the common white ware, richly daubed with blue, to imitate the unmeaning scenes painted on the Chinese porcelain: since his time the manufactures of Staffordshire have become celebrated at home and abroad. Among these, however, the modern Etruria, occupied at present by the sons of Mr. Wedgwood, still bears a distinguished sway, and must continue to be conspicuous, so long as they possess the same spirit of improvement, to which their present establishment owes its existence.

Although very different combinations of the earth, and sometimes metallic oxyds are employed in the manufacture of earthen-ware, the ductility of these compounds, or that which admits of their being moulded into different forms, is peculiar to alumine or argillaceous earth. The natural compounds, commonly called clays, consist of pure clay or alumine, combined with silica, lime, and sometimes magnesia, and frequently also with oxyd of iron. In this latter case the pottery burns to different shades of red, proportionate to the quantity of iron. When magnesia is combined, it gives to it a soapy feel, from which it has obtained the name of soap-rock. A marked variety of this is called steatite.

The clay from which the Staffordshire ware is manufactured comes from Dorsetshire, and another variety of inferior quality from Devonshire. These are both of excellent quality for working, and possess great whiteness when burnt. These clays are valued particularly for the latter property, which arises from their being free from iron, which would give them a yellow or reddish colour.

The clay undergoes such preparation at the place where it is procured, as to free it from stones and many other impurities. In the manufactory of Mr. Wedgewood, the molt complete in the kingdom, the clay is thrown into a cylinder of cast metal, four feet high and twenty inches in diameter. In the middle of this cylinder runs a perpendicular shaft, with knives as radii at right angles to the shaft. These knives are so arranged upon the shaft, that their flat sides are in the plane of a spiral thread, so that by the revolution of the shaft the knives do not only cut any thing in their way, but constantly force downwards what may be in the cylinder, agreeably to the nature of the screw. Another set of knives is inserted in the interior surface of the cylinder, and extend to the shaft in the centre: these correspond with, and are parallel to, the moveable knives. The two sets, the one active, the other passive, have the effect of sheers in cutting the clay into small pieces, while the spiral form of the active knives forces the clay in its reduced state out at an aperture at the bottom of the cylinder, from whence it is transferred to a vat, for the purpose of mixing the clay with water. This vat is of a cylindrical form, the diameter being about four times the height. In the centre of this vat turns a perpendicular shaft, having cross arms or radii one below the other. These are connected by perpendicular flaves, giving the moveable part the appearance of two opposite gates, upon the central shaft. These gates revolve in the cylinder just immersed in the pulp, the constant agitation mixing all the fine particles completely with the water, while the stony particles of greater magnitude remain at the bottom. The pulp is now passed off from this vat through a series of sieves of different degrees of firmness, which work backward and forward by machinery: this separates the gross parts from that which is fitted to enter into the composition of the ware. We will here leave this refined pulp, to go to the preparation of the flint, a certain portion of which is necessary to be united with the clay pulp, in order to constitute the potter's mass.

The flint in its crude state is the common flint used for striking fire, which principally consists of pure flint. It is first placed in a kiln and heated to a red heat; and while red-hot thrown into cold water. This process is to lessen its aggregation, and make it easier to reduce to powder. Mr. Wedgewood reduces the flints into small pieces by means of hammers, which are worked by machinery. The pieces are laid upon a strong grating, so that as they become of a certain size, they are driven through the divisions of the grate. After this process they are taken to a mill, which consists of a cylindrical pan, similar to that used for mixing the clay with water, but the arms of the upright shaft are made to carry large stones of great hardness: the stone is known by the name of *chert*. These stones are fastened to the arms of the upright shaft, so that the under side, which is perfectly flat, may move over similar passive stones. This cylindrical pan contains a certain quantity of water when the small masses of flint are introduced. The flint soon gets between the chert surfaces, which from their great hardness reduce the flint to a pulpy consistence. The finer particles become suspended in the fluid, and are run off from time to time near the top of the pan. This pulp is then passed through lawn or silk sieves in a manner similar to the clay, the part which remains in the sieve being returned to the mill to be ground over again. The pulp is always made to a certain consistence, with a view to know what quantity of flint is contained in a given measure, and the same with regard to the clay in the same state. The two pulps are now mixed together in such proportion

by measure, that the flint bears a proportion to the clay of about one to five, and sometimes one to six. They are now intimately mixed together, by an apparatus similar to that employed for mixing the clay with the water in the first instance.

It is a well-known fact that clay, when exposed to the fire, continues to shrink to the greatest heat of the best furnaces. This contraction doubtless goes on till the whole of the water is dissipated, and the clay undergoes fusion. This phenomenon is more conspicuous when the clay is pure alumine. Hence we should expect, if the clay were pure, that the same degree of heat in such clay ought to produce the same decrease of volume. The application of this principle to measure high temperatures, did not escape the sagacity of the late Mr. Wedgewood. He constructed a thermometer which measured the degree of heat in which bits of pure clay had been exposed, by their shrinkage. Plausible, however, as this idea may appear, it became almost impracticable, from the circumstance of the shrinkage of different bits, made from the same mass of clay, not being uniform.

It is found that, in proportion as pure clay is combined with the other earths, it undergoes less shrinkage; and since the great shrinkage in the manufacture of earthen-ware is attended with other inconveniences, the flint is added for the purpose of preventing the shrinkage to a certain extent. It will appear that when the shrinkage is the greatest, the ware will be the most dense, and will afford a closer fracture. Under these properties the articles are less fitted to withstand sudden changes of temperature. The shrinkage may also be diminished by pounding pieces of well-burnt clay, and mixing them with the clay that would be liable to shrink. This expedient is often resorted to in making crucibles, which require to be made of the purest clay, on account of their essential property of infusibility.

When the flint and clay, in their pulpy state, have been intimately mixed, the next process is to separate the excess of water, which is effected by evaporation. The vessel in which the pulp is placed for evaporation should expose a great surface, its breadth being about five or six feet, its length 20 to 30, and very shallow. The bottom is made of fire-bricks, and the flame of the fire, which is at one end of the brick-work, passes along a flue under the bottom. The evaporation is slow, on account of the bricks being bad conductors of heat. This inconvenience, however, is compensated by the uniform consistence which the evaporating mass acquires. When the evaporation has been continued till the mass is sufficiently stiff, it is cut out in cubical masses, and is next subjected to a process, by which the mass is rendered of uniform stiffness throughout, and fit for working. This change is brought about in the most complete manner, by allowing it to remain in a heap for a considerable time. The water in the clay may be considered as a chemical compound. Hence we may conceive that the water, by time alone, will constantly be tending to uniformity throughout the whole mass.

The operations by which this effect is facilitated, are, first by hand, and secondly, by a machine for the purpose. The first is called *sloping* or *wedging*, and consists in taking a mass of clay in both hands, and with a twist of both at the same time, the piece is separated into two pieces. They are now brought together with greater violence, but in different parts to those just separated. The piece is now separated at right angles, and two new surfaces brought in contact. This change of surface every time, sometimes 20 or 30 times, effects the uniform mixture of the different parts so completely, that if, at the commencement of the operation, the mass consisted of two distinct pieces, one black and the

other white, at the end of the operation the mafs would become of an uniform grey colour.

This latter process is usually practised immediately before the clay is made in mafes of proper size for working into different articles.

This change is also effected with more difpatch by a machine, very fimilar to that firft ufed for cutting the crude clay into pieces.

An upright shaft works in a cylinder of caft iron; from this the radiant knives work in the plane of a fpiral thread, extending to the circumference of the cylinder. The pieces of clay are thrown into the cylinder in the ftate they are cut out of the evaporating vefel. The knives firft act by cutting them in pieces, and force them down the cylinder like a fcrew. From the bottom of the cylinder extends an horizontal opening in the form of a parallelepipedon, the fection being about fix inches fquare. The clay is forced through this opening, and cut off in lengths of about one foot each. Thefe mafes are again thrown into the cylinder, and pafled through in the fame way feveral times, till they are deemed in a proper ftate. The mafes are now, when time will admit, laid together for fome time, as the workmen find that they work much better for lying longer. This we have accounted for from the equal force of affinity, which tends to eftablifh an equilibrium of the attractive force of the clay for water in every part of the mafes.

Having prepared the material, we will now proceed to defcribe the methods of forming it into articles of various forms. This is fo very fimilar to the methods ufed in the manufacture of porcelain, which we have already defcribed, that we fhall merely ftate fome improvements in the machinery introduced by Mr. Wedgewood. The potter's lathe, which is ufed for throwing the different articles of a circular form, confifts of a perpendicular shaft about three feet high, having a circular piece of wood at the top, the face of which, by the shaft, turns parallel to the horizon. The lower end of the shaft runs in a ftep; the upper part has a neck a little below the circular piece of wood, which works in a focket. Formerly this perpendicular shaft was put in motion by a wheel, with fpokes fattened upon it, which the workman moved with his foot. In others the shaft has a crank in the middle, with a long rod working upon it. This being pushed backward and forward by a fecond perfon, gave motion to the lathe. In the *porcelain* works of this country, as has been defcribed under that article, the lathe is generally turned by a rope paffing from a pulley upon the perpendicular shaft to a large wheel at a diftance, which is turned by a boy. The firft of thefe methods is convenient, as the workman can beft fuit the velocity to the ftate of the work, which varies very confiderably in throwing the fmalleft article. The labour, however, is fo great, that in throwing large articles there would be great time loft. The two other methods, although they afford much eafe to the workman, are very inconvenient, as the thrower has continually to be fpeaking to the turner, in order to get the proper increafe of fpeed. Mr. Wedgewood has the whole of his lathes, both for throwing and turning, turned by the ftream-engine. The perpendicular shaft of the lathe is moved by an horizontal one, which is connected by two bevel wheels. The horizontal shaft is provided with a long drum, from which a ftrap ascends to two conical drums reverfed, and working together: this allows the ftrap to keep at the fame degree of tightnefs, while it traverses from one end of the drum to the other. From thefe drums, which are moved by the principal one, motion is given to the lathe. During the throwing of any article, a feparate piece of machinery is turned by a boy, which caufes the ftrap to move, parallel to itfelf, along

the drum of the horizontal shaft, and at the fame time along the conical drum. This changes the velocity very gradually to its maximum, and returns to its floweft motion, when the workman is finifhing the article thrown; the ftrap is then thrown on to a loofe pulley, which flops the lathe. The clay is firft portioned into pieces fufficient for the article intended. At the fame infant that the thrower places the pieces of clay on the face of the circular board, the ftrap is transferred from the loofe pulley, and the motion commences. The boy, by turning a winch, begins to move the ftrap from the fmall end of the conical drum to the large end, when the velocity is at its maximum, and when the thrower, by means of his wet hands and a thin piece of wood, is giving the proper fhape to the clay. At this point he begins to finifh the article, and the ftrap is caufed to move back from the large to the fmall end of the drum, when the work is finifhed, the machine is flopped, and the thrown article cut off at the bafe with a piece of fmall wire. It is now carried to a proper place to be dried. When it has been dried to a certain extent, which the workmen call the green ftate, it is then taken to the turning lathe, which is fimilar to the common lathe ufed for turning wood. Thefe lathes, in Mr. Wedgewood's works, are turned by the ftream-engine, and as, during the turning of each vefel, the velocity requires to be varied, the motion is communicated from two conical drums, fimilar to the throwing lathe, and the ftrap is made to traverse the drums by a motion given by the foot of the turner. There is alfo a contrivance for reverfing the motion, by which the turned furface is polished.

The fame degree of drynefs which admits of the clay being turned in the lathe, to give it its proper finifh and fmoothnefs, is alfo the proper ftate for fixing on the handles or other appendages, which cannot be effected in the lathe. The parts to be added are preioufly made, and at a proper degree of drynefs are attached to the round work by means of a pulpy maf, formed by clay mixed with water, which the workmen call *flip*. The joined parts are then fmoothed off with a wet fponge. In this ftate they are taken to a ftove, which is nothing more than a room provided with fhelves, raifed from 80 to 90 degrees of temperature. When they are fully dried, if the articles be of fuperior quality, they are rubbed over with a fmall bundle of hemp, in order to take off any fmall bits left after the turning and handling, and to fmooth thofe parts which cannot be turned. The ware is now ready for the kiln, which is to convert it from a foft and tender ftate to a hard fubftance, called *biscuit*.

A great variety of pottery cannot be made on the lathe, its not being of a circular form. This is made by two different methods, the one called prefs-work and the other cafting. The prefs-work is formed in moulds made of plafter, one half of the figure being on one fide of the mould, and the other half on the other fide: thefe fit accurately together. The clay is firft made into two flat pieces, of the thicknefs of the articles: one of thefe is preffed into one fide of the mould, and the other into the other fide, the fuperfluous clay being cut away, leaving it a little fufh above the mould. The two fides of the mould are now brought together to unite the two halves of the article. The mould is now to be feparated from the clay, and the article is finifhed as to form. It is now dried to the green ftate, when it is completed with any other parts to be added. All vefels of an oval form, or fuch as have flat fides, are made in this way. The fpouts of tea-pots, and all fimilar articles, are made in two halves in a fimilar way, and are attached to the vefels in the green ftate, when the handles are alfo put on. The handles, which are fometimes of an oval fhape in their fection, others fluted

other white, at the end of the operation the mass would become of an uniform grey colour.

This latter process is usually practised immediately before the clay is made in masses of proper size for working into different articles.

This change is also effected with more dispatch by a machine, very similar to that first used for cutting the crude clay into pieces.

An upright shaft works in a cylinder of cast iron; from this the radiant knives work in the plane of a spiral thread, extending to the circumference of the cylinder. The pieces of clay are thrown into the cylinder in the state they are cut out of the evaporating vessel. The knives first act by cutting them in pieces, and force them down the cylinder like a screw. From the bottom of the cylinder extends an horizontal opening in the form of a parallelepipedon, the section being about six inches square. The clay is forced through this opening, and cut off in lengths of about one foot each. These masses are again thrown into the cylinder, and pulled through in the same way several times, till they are deemed in a proper state. The masses are now, when time will admit, laid together for some time, as the workmen find that they work much better for lying longer. This we have accounted for from the equal force of affinity, which tends to establish an equilibrium of the attractive force of the clay for water in every part of the mass.

Having prepared the material, we will now proceed to describe the methods of forming it into articles of various forms. This is so very similar to the methods used in the manufacture of porcelain, which we have already described, that we shall merely state some improvements in the machinery introduced by Mr. Wedgwood. The potter's lathe, which is used for throwing the different articles of a circular form, consists of a perpendicular shaft about three feet high, having a circular piece of wood at the top, the face of which, by the shaft, turns parallel to the horizon. The lower end of the shaft runs in a step; the upper part has a neck a little below the circular piece of wood, which works in a socket. Formerly this perpendicular shaft was put in motion by a wheel, with spokes fastened upon it, which the workman moved with his foot. In others the shaft has a crank in the middle, with a long rod working upon it. This being pushed backward and forward by a second person, gave motion to the lathe. In the *porcelain* works of this country, as has been described under that article, the lathe is generally turned by a rope passing from a pulley upon the perpendicular shaft to a large wheel at a distance, which is turned by a boy. The first of these methods is convenient, as the workman can best suit the velocity to the state of the work, which varies very considerably in throwing the smallest article. The labour, however, is so great, that in throwing large articles there would be great time lost. The two other methods, although they afford much ease to the workman, are very inconvenient, as the thrower has constantly to be speaking to the turner, in order to get the proper increase of speed. Mr. Wedgwood has the whole of his lathes, both for throwing and turning, turned by the steam-engine. The perpendicular shaft of the lathe is moved by an horizontal one, which is connected by two bevel wheels. The horizontal shaft is provided with a long drum, from which a strap ascends to two conical drums reversed, and working together: this allows the strap to keep at the same degree of tightness, while it traverses from one end of the drum to the other. From these drums, which are moved by the principal one, motion is given to the lathe. During the throwing of any article, a separate piece of machinery is turned by a boy, which causes the strap to move, parallel to itself, along

the drum of the horizontal shaft, and at the same time along the conical drum. This changes the velocity very gradually to its maximum, and returns to its slowest motion, when the workman is finishing the article thrown; the strap is then thrown on to a loose pulley, which stops the lathe. The clay is first portioned into pieces sufficient for the article intended. At the same instant that the thrower places the pieces of clay on the face of the circular board, the strap is transferred from the loose pulley, and the motion commences. The boy, by turning a winch, begins to move the strap from the small end of the conical drum to the large end, when the velocity is at its maximum, and when the thrower, by means of his wet hands and a thin piece of wood, is giving the proper shape to the clay. At this point he begins to finish the article, and the strap is caused to move back from the large to the small end of the drum, when the work is finished, the machine is stopped, and the thrown article cut off at the base with a piece of small wire. It is now carried to a proper place to be dried. When it has been dried to a certain extent, which the workmen call the green state, it is then taken to the turning lathe, which is similar to the common lathe used for turning wood. These lathes, in Mr. Wedgwood's works, are turned by the steam-engine, and as, during the turning of each vessel, the velocity requires to be varied, the motion is communicated from two conical drums, similar to the throwing lathe, and the strap is made to traverse the drums by a motion given by the foot of the turner. There is also a contrivance for reversing the motion, by which the turned surface is polished.

The same degree of dryness which admits of the clay being turned in the lathe, to give it its proper finish and smoothness, is also the proper state for fixing on the handles or other appendages, which cannot be effected in the lathe. The parts to be added are previously made, and at a proper degree of dryness are attached to the round work by means of a pulpy mass, formed by clay mixed with water, which the workmen call *slip*. The joined parts are then smoothed off with a wet sponge. In this state they are taken to a stove, which is nothing more than a room provided with shelves, raised from 80 to 90 degrees of temperature. When they are fully dried, if the articles be of superior quality, they are rubbed over with a small bundle of hemp, in order to take off any small bits left after the turning and handling, and to smooth those parts which cannot be turned. The ware is now ready for the kiln, which is to convert it from a soft and tender state to a hard substance, called *biscuit*.

A great variety of pottery cannot be made on the lathe, its not being of a circular form. This is made by two different methods, the one called press-work and the other casting. The press-work is formed in moulds made of plaster, one half of the figure being on one side of the mould, and the other half on the other side: these fit accurately together. The clay is first made into two flat pieces, of the thickness of the articles: one of these is pressed into one side of the mould, and the other into the other side, the superfluous clay being cut away, leaving it a little flush above the mould. The two sides of the mould are now brought together to unite the two halves of the article. The mould is now to be separated from the clay, and the article is finished as to form. It is now dried to the green state, when it is completed with any other parts to be added. All vessels of an oval form, or such as have flat sides, are made in this way. The spouts of tea-pots, and all similar articles, are made in two halves in a similar way, and are attached to the vessels in the green state, when the handles are also put on. The handles, which are sometimes of an oval shape in their section, others fluted

through it. This valuable property of biscuit earthen-ware has lately been applied to the construction of vessels for cooling wine and other liquids. The water passes from the inner to the outer surface, and constantly presents a humid surface to the atmosphere, which by evaporation carries off much more heat than would be carried off from dry surfaces. Mr. Leslie has lately made an useful instrument, by taking advantage of this property of the biscuit for shewing the evaporating power of the air.

The next process is to render the biscuit fit to hold liquids, by filling up the pores, and coating the surface with a vitreous substance. This process is called glazing. A great variety of substances may be used for this purpose. Pounded glass would constitute a glazing for earthen-ware, where the colour of the body is wished to be seen through the glazing. The composition for earthen-ware, which we have given in this account, is capable of forming two varieties merely from the nature of the glazing. When the glazing is transparent and colourless, the colour of the body is seen, which having a yellowish tint from the presence of a small quantity of oxyd of iron, it is called cream-coloured ware. When the glazing is rendered a little opaque and of a blueish tint, by the presence of tin or arsenic, and a small portion of oxyd of cobalt, it acquires a milky or opal appearance of a blueish-white colour. The glazing formed with pounded glass, may be considered as a compound of flint and potash, or soda; hence it can be made of different degrees of fusibility by the addition of flint or alkali. These glazes are found to have some inconveniences, the principal of which is their not expanding and contracting equably with the body. The glaze is liable to crack and sometimes peel off. Earthen-ware glazed with this substance may be frequently observed to abound with innumerable cracks on the surface, which are permeable to grease or any other fluid. Such vessels soon become very disagreeable, especially when heat is applied to them, capable of burning the substances by which they have been penetrated.

No glazing has yet been discovered for common earthen-ware which is free from the above objection, without the use of lead, which, on account of the poisonous quality of that metal, should, if possible, be avoided. The oxyd of lead, even in its vitreous state, and combined with flint or clay, is so completely soluble in acids, that bad consequences have arisen by eating pickles from jars glazed with lead.

The transparent glaze used for the cream-coloured ware, is generally composed of oxyd of lead and ground flint, in equal weights. White lead is preferred, but it is not so economical as litharge or minium. In the commonest earthen-ware, galena (sulphuret of lead) is made use of. The oxyd of lead and the flint are first ground to an extremely fine powder, and then mixed with water, to give the whole the consistency of cream. The biscuit, being first made clean, is dipped into the pulp, and drained out: it is then turned about rapidly into various positions, to prevent the glaze from lying thicker in one place than another. During this change of position the water of the glaze is absorbed by the biscuit, leaving the solid matter of uniform thickness upon the surface. This part of the process is called dipping. The ware is now placed in the sagars and put in the kiln, exactly the same as in the biscuiting process. The fire is not raised so high, nor so long continued, being only sufficient to bring the glaze into perfect fusion. Dishes and plates, when placed in the sagars for glazing, may be put one upon another, by placing small stands of earthen-ware between them, presenting three small points only to each of the surfaces. When this ware is brought from the kiln, it is considered finished.

The ware called white ware is made of the same material, and manufactured precisely in the same way, as far as the biscuiting. Formerly it used to be painted after glazing, and had a second firing, similar to porcelain. It is now printed with copper-plate prints almost always with oxyd of cobalt, which makes the figures of a blue colour. It is in this state called blue and white ware, and constitutes an important branch of the Staffordshire pottery. The subjects of the prints are generally vile imitations of the paintings on the Chinese porcelain, which are of themselves shocking.

The printing is performed while the ware is in the state of biscuit, and the glazing laid over the colouring matter. The designs for the ware are engraved upon copper-plates, and prints taken from these, as in common copper-plate printing. The surface of the paper to receive the impression is first smeared over with soft soap. The plate and the rolling-press are constantly kept warm. The colouring, which for the *blue and white ware* is oxyd of cobalt, is greatly diluted with some colourless earthy matter: it is ground up with boiled linseed oil, such as is used for printing ink: its consistency, when laid on the plate, being that of soft paste. The paper, prepared as above mentioned, is now laid upon the plate, and passed through the rolling-press. The printed part is now cut out of the paper, and being moistened is laid upon the biscuit. The colouring matter is now instantly absorbed by the biscuit. This being done, the paper is washed from the biscuit in a tub of clean water. The colouring matter will now be seen very plain on the surface of the pottery.

The ware, having received the colouring matter, is now set to dry up the water, and is then dipped in the glazing pulp precisely in the same way as the cream-coloured ware. The glazing material, it will be remembered, differs a little from the latter, in containing a little oxyd of cobalt, which gives it a blueish tint, and gives the idea of greater whiteness. The goods are fired in sagars, as has been already described. The oxyd of cobalt now becomes of a beautiful blue, under the glaze. If, instead of the cobalt, a mixture of the oxyds of iron and manganese be employed, the figures will appear of a black colour, which gives the effect of an engraving, and is much more beautiful and consistent than the cobalt. In some potteries *penicilling* is practised to great extent. This consists in laying on the colour with enamel, after the glazing. This work is very expensive, and is not so general as formerly. This process is so similar to that used in painting *porcelain*, that we shall refer the reader to that article.

Lately, another variety of ware has been introduced, which is by the potters called *lustre*: it consists in fixing gold or platina upon the surface of the glazing. The substance from which the platina lustre is procured, is obtained by dissolving platina in equal parts of the nitric and muriatic acids with heat. When the whole is dissolved, add to the solution a solution of muriat of ammonia, but yellow precipitate will fall to the bottom: continue to add the latter till no more is precipitated: decant off the clear liquor, and add fresh portions of hot water, till it becomes tasteless: drive off the first portion of water by heat, and preserve the dry powder for use: let this powder be ground, with a small portion of enamel, in oil of turpentine: spread this thinly over the glazed surface of the plain earthen-ware above described. The ware is now to be exposed to the heat of an enamel kiln, which is a red heat. The platina assumes its metallic form, which acquires greater brilliancy by the presence of the glaze.

The precipitates from gold may be laid on in the same way. The glazed ground, however, on which the gold is

laid, is of a brown colour by adding the oxyds of iron and copper to the glazing matter. By this means the yellow colour of the gold with the brown glaze, gives the lustre the colour more of copper than of gold. It is probable that the lustre is, or may be produced by smearing the glazed surface with the liquid solution of the metal, in a very dilute state. The liquid may contain a little gum, and a little enamel mixed with it, when spread upon the articles to be lustrified.

A very coarse earthen-ware made in Persia, which we have alluded to in a former part of this article, possesses metallic lustre, which is doubtless given by gold in the way just described.

The most perfect pottery, particularly so far as regards excellence of workmanship, has been manufactured by the late Mr. Wedgwood, and since by his sons. Among the most superb of their productions are their imitations of jasper, manufactured into vases, medallions, and other ornamental forms. The substance of which they form their mortars, and a variety of chemical utensils, is extremely hard, and is not acted upon by acids.

The black and the yellow ware made by Messrs. Wedgwoods, of which the late Mr. Wedgwood was the inventor, possesses great elegance, and a very compact body. The black ware owes its colour to the presence of oxyd of iron, and a small portion of oxyd of manganese. The yellow ware, which is similar in texture, owes its colour to the presence of a little iron alone. A great number of places furnish natural products capable of assuming this yellow tint. The compactness of the body is effected by using less flint in the composition, and giving it more heat in the burning. This biscuit is so compact that it does not require to be glazed, and this is what constitutes its great excellence. Its beauty is much greater in being destitute of the glaze or vitreous coating, which, when it is managed in the best way possible, is but a miserable imitation of a polished surface. That species of ware which, from its great hardness, has been called stone-ware, is not encouraged so much as it deserves. It is employed for the most common, and the cheapest articles, when it ought to be used for all domestic pottery. Every other kind, excepting the true porcelain, is objectionable on account of its porous texture, and the lead contained in their glaze. Every species of clay capable of bearing a great heat, may be employed in the manufacture of stone-ware. Those which contain much oxyd of iron cannot be employed, as they would be liable to soften, and even to melt in the heat required for glazing.

This manufacture is at present almost entirely confined to bottles, particularly those used for soda water and artificial mineral waters, their texture being sufficiently close to hold gas compressed to several atmospheres.

The clay is prepared in the same way with that used in making the pottery already described. Indeed, there would be no difference in preparing the vessels for the kiln, whether formed by throwing, pressing, or casting. It is simply in the burning and glazing that the difference consists. In making the common articles, the vessels are piled up in the kiln, and exposed to the naked fire, without being defended by fagars. It is on this account that they receive a much greater heat than the common earthen-ware. When the heat has arrived at its maximum, a quantity of common salt (muriate of soda) is thrown into the body of the kiln. The salt rises in vapour, which speedily envelopes the hot ware, and glazes it as completely as in any other way, if the heat be sufficient. It is likely that the salt is decomposed, the acid flying off, while the soda combines with the earths of the pottery, forming a vitreous coating. The smoke being in

contact with the ware, gives it a brownish colour. The fracture is close and compact, and its strength much greater than the common white ware. This pottery might be extended to a variety of other articles for culinary purposes, and with proper contrivance in the construction of the kiln, articles might be made with as much taste and elegance as any other.

When the Dorsetshire clay is employed, and the ware defended from the smoke while burning, and at the time the salt is thrown in, the colour of the ware would be white, and the glaze transparent. When the clay is not sufficiently white, it may be rendered so superficially by dipping the dry ware, before it goes into the kiln, into a mixture of Cornwall clay and water in the state of a thin pulp. It is taken out, and turned about, as in glaze dipping, in order to spread the coating uniformly. The water is absorbed by the dry ware leaving a coating of the white Cornwall clay upon the surface. A dip made with water and a fine powder of the Cornwall stone, would answer better than the latter, as it would more easily fuse with the sublimed salt. The whiteness of the Dutch tiles is produced in this way, as the body will be found of a dirty grey colour.

The most common and worst kind of earthen-ware made in this country is formed of common clay used for bricks. The ware, after being rudely formed, is very slightly burnt, and afterwards glazed with a composition of galena (sulphuret of lead), oxyd of manganese, and the clay of the ware. The glaze is of a dark colour, approaching to black. The lead in this ware is easily attacked by acids, and should not be used where they are liable to be present. The same earthen-ware, unglazed, is used for garden pots, tiles, and tubes for draining land.

We shall conclude this article with some account of the methods of forming crucibles, retorts, and tubes of earthen-ware.

These vessels are required to possess two very essential qualities; first, they should bear the naked fire without cracking; and, secondly, they should bear the heat of the hottest furnaces without fusing. The retorts and the tubes should at least possess the first property, and require a greater closeness of body more than that required for crucibles.

The crucibles called Hellian crucibles have held a high character, both on the continent and in this country, but they are not useful for all purposes. The Dutch crucibles, which contain plumbago, are well calculated to bear sudden changes of temperature, but become very tender, and fuse at a high temperature.

A similar manufacture is carried on at Chelsea; the crucibles are quite as good as the Dutch ones, and of a much better form.

Very excellent crucibles are made of the Stourbridge clay, particularly for melting cast-iron and steel. This clay is worked up with the powder of the broken pots, which has the effect of making the pots stand sudden changes of temperature. It has been lately found, in the cast-steel works at Sheffield, that the best crucibles for their purpose are formed of the Stourbridge clay, worked up with powdered coak of pitcoal. This enables the crucibles to bear sudden changes of temperature, and at the same time to bear the greatest heat of our best air-furnaces. The Cornish clay might be used with pounded coak with similar success, and might perhaps be superior to the Stourbridge clay for earthen retorts and tubes. None of these articles should be very hard burnt, as they will, in consequence, be more liable to crack with sudden heat, and even in the regular way of bringing them up with the fire.

POTTERY, *Chinese*. See PORCELAIN.

POTTERY, *The, or The Potteries, in Geography*, an extensive tract of country in the hundred of North Pyrehill, and county of Stafford, England, comprehends an area of about eight miles long and six broad, and is perhaps the most populous and busy of any district of similar extent in Great Britain. It derived its name from being almost exclusively appropriated to extensive manufactories of earthenware, for which its situation and peculiar characteristics are excellently adapted. The soil presents, in almost every part, a great variety of clays; covering rich and productive strata of coal, which lying in general near the surface, are wrought at a comparatively small expence. These strata are usually divided by veins of clays, most of which form excellent fire-bricks for constructing potter's kilns and fagars, to burn the ware in. Finer clays also are plentiful in many places; of which in former times the bodies of the wares themselves were wholly manufactured. To these advantages, joined to the inaptitude of the soil for husbandry purposes, this district is doubtless indebted for its selection as the seat of its present staple manufactories. When this originally occurred is utterly unknown, but the existence of some kind of earthenware manufactory can be traced at least two centuries back. Its principal seat at that period was the town of Burslem, which was called a butter pottery; that is, a manufactory of pots for the preservation of butter; and under that name it is marked in several old maps: but this establishment seems to have been, even so late as the year 1686, very inconsiderable, as Dr. Plot, in his "Natural History" of the county, says, that the sale of its products was chiefly "to the poor crate-men, who carried them *at their backs* over all the country." All the ware was then of a coarse yellow, red, black, and mottled kind. The common glaze was produced by lead ore finely powdered, and sprinkled upon the pieces of ware before firing; sometimes with the addition of manganese. Occasionally, when the potter wished "to shew the utmost of his skill," he employed, instead of lead ore, calcined lead itself, but still sprinkled it on, in the same rude manner.

The era of improvement commenced about the year 1690, when two ingenious Dutchmen, of the name of Elers, settled here, and introduced the practice of adding common salt to the clay when at its highest heat, in order to give it a superficial vitrification. The same individuals also introduced the manufacture of a new species of ware, in imitation of the unglazed red china of the East; and the clays here being suitable for the purpose, they succeeded wonderfully for a first attempt, so that many of their tea-pots are said to have sold as high as a guinea each. The next improvement was made in the substance of the ware itself by a Mr. Astbury, as tradition asserts, through this incident. Being on his way to London, he happened to have powdered flint recommended to him to cure some disorder in his horse's eyes, and accordingly a flint stone was thrown into the fire, to render it more easily pulverable, which changing to a pure white by the influence of the heat, the potter was struck with the idea, that his ware might be improved by an addition of the same material to the whitest clays. He tried the experiment with tobacco-pipe clay, and the event proved fully answerable to his expectation. Thus originated the *white stone wares*, which soon supplanted the coloured ones, and continued for many years the staple branch of pottery in this country.

It was, however, about the year 1760, that the most important improvements began to be made in the Staffordshire potteries, by the late Josiah Wedgewood, esq. This gentleman not only improved the composition, forms, and colours of the old wares; but likewise invented, in 1763, a new

species of ware, for which he obtained a patent, and which being honoured by her majesty's approbation and patronage, received the name of Queen's ware. Continuing his experimental researches, Mr. Wedgewood afterwards invented several other species of earthenware and porcelain, of which the principal are: 1. *A terra cotta*; resembling porphyry, granite, Egyptian pebble, and other beautiful stones of the siliceous or crystalline order. 2. *Basaltes*, or *black ware*; a black porcelain biscuit of nearly the same properties with the natural stone, receiving a high polish, resisting all the acids, and bearing without injury a very strong fire. 3. *White porcelain biscuit*; of a smooth wax-like appearance, of similar properties with the preceding. 4. *Jasper*; a white porcelain of exquisite beauty, possessing the general properties of basaltes; together with the singular one of receiving through its whole substance, from the admixture of metallic calces, the same colours which those calces give to glass or enamels in fusion; a property possessed by no porcelain of ancient or modern composition. 5. *Bamboo*, or cane-coloured biscuit porcelain, of the same nature as the white porcelain biscuit. And 6. *A porcelain biscuit* remarkable for great hardness, little inferior to that of agate; a property which, together with its resistance to the strongest acids, and its impenetrability to every known liquid, renders it well adapted for the formation of mortars, and many different kinds of chemical vessels. For some further account of this gentleman's discoveries; see WEDGEWOOD, JOSIAS.

The above six distinct species of ware, together with the queen's ware first noticed, have increased, by the industry and ingenuity of different manufacturers, and particularly by Mr. Wedgewood and his son, into an almost endless variety of forms for ornament and use. These, variously painted and embellished, constitute nearly the whole of the present fine earthenwares and porcelains of English manufacture.

The number of persons who derive their support from the manufacturing part of the pottery business alone, including the wives and children of those employed in it, is computed to exceed 25,000 persons; and probably three times that number depend for bread on the labour it creates, particularly in the collieries, in procuring the raw material from several distant parts of the kingdom, and in the inland navigation connected with the same, and of the manufactured product. The pottery district lies chiefly in the parishes of Burslem and Stoke; and, as happens in most manufacturing districts, it is remarkable for the great diversity of opinion which prevails among its inhabitants on the subject of religion. Of the various sects, however, the Methodists claim a decided superiority, in point of number, over all the others. The principal towns and hamlets comprised within the limits of The Pottery, are Stoke, Hanley, Shelton, Golden-Hill, New-Field, Smith-Field, Tunstall, Long-Port, Burslem, Cobridge, Etruria, Lane-End, Lower-Lane, and Lane-Delft.

Stoke, or, as it is commonly called, Stoke-upon-Trent, has recently been constituted a market-town; and has a market-house furnished with all the accommodations requisite for its object. The church is an ancient and spacious edifice, in the later Norman style of architecture. Like most other parts of The Pottery, this town has increased in size and importance since the Staffordshire canal was cut. It contains many handsome buildings; and from its proximity to a wharf upon the canal, is most conveniently situated for trade. At this place the first steam-engine for grinding burnt flints, erected in this country, was established about twenty years ago by a gentleman named Spode. The earthenware manufactories here are numerous; and many of them are upon

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an extensive scale. Close to the town the canal is carried over the river Trent, by means of an aqueduct constructed entirely of brick.

Hanley is situated about two miles northward from Newcastle-under-Line. This town also has a weekly market on Monday; and is distinguished for the neatness and regularity of its streets, and the elegance of many of the houses which compose them. Here is a church, which was founded in 1788; also several chapels and meeting-houses appropriated to the worship of dissenters.

Shelton is a very extensive place, but has not hitherto been constituted a market-town. It is particularly deserving of notice on account of its china manufacture, which rivals the famed porcelain of the East. The ingenious Mr Champion of Bristol, who discovered the art of making this species of ware, expended an ample fortune in various trials, but having succeeded ultimately in bringing it to perfection, he obtained a patent for it, which he sold to the firm of Hollins, Warburton, and Co. As the canal passes Shelton, there are a public wharf and store-houses upon it, for the landing and safety of goods.

Golden-Hill, from its name, one would suppose to be a considerable and even splendid place; but on comparison it is found to be the least so of any in The Pottery. Its valuable mines of coal, however, make ample amends for its other deficiencies, and from the richness of those mines it derived its name. At the upper end of this village is Green-lane, which commands a most unbounded and beautiful prospect, on the one side over the greater part of Cheshire, and on the other over the whole extent of The Pottery, and a large portion of the country adjoining.

New-Field is well situated for manufacturing purposes, from the great plenty of coal in its immediate vicinity, but as it belongs wholly to one person, who has a handsome seat close to the village, there are fewer pottery establishments here than would otherwise have been the case.

Smith-Field, like *New-Field*, is well situated for carrying on pottery manufactories, having several strata of coal and clay close adjoining; but similar reasons prevent their being increased and extended in the same proportion as in some of the other villages in the district.

Tunstall, including its environs, is the pleasantest village in The Pottery. It stands upon high ground, at the distance of four miles northward from Newcastle, and appears to have been formerly the site of a religious institution, of which some remains were visible about the middle of the last century. These, however, are now completely gone; and a neat chapel has been erected on or near the spot which it occupied. The principal works here are for bricks and tiles; the clay being of a very superior kind for the manufacture of such articles. The tiles made from it, in-

deed, by good management take a blue colour, which renders them almost as fit for roofing as slates.

Long-Port is situated in a valley between Newcastle and Burslem. It has many good buildings in it, and several large and extensive manufactories; but owing to its low position, it is at times disagreeable from the smoke hanging upon it longer than it commonly does upon higher ground. The Staffordshire canal passes this village, and has a public wharf upon it.

Burslem, as already stated, is the most ancient town in the whole Pottery, and was undoubtedly the first seat of the earthen-ware manufacture in Staffordshire, and perhaps in Great Britain. Plot, in his "Natural History" of the county, makes particular mention of the potteries at this place, and points them out as the greatest of the kind then known. This author, likewise gives an ample detail of the process of making the ware in his days. Burslem has two markets weekly on Monday and Saturday, but that on Monday is by far the most considerable. Here are also regular annual fairs, established about twenty years ago, for the sale of cattle. The church, which is parochial, is an ancient structure, but has been much altered, enlarged, and modernized within the last twenty years. The Methodists have two chapels in Burslem, and are very numerous. In this town is a great variety of other sectarians.

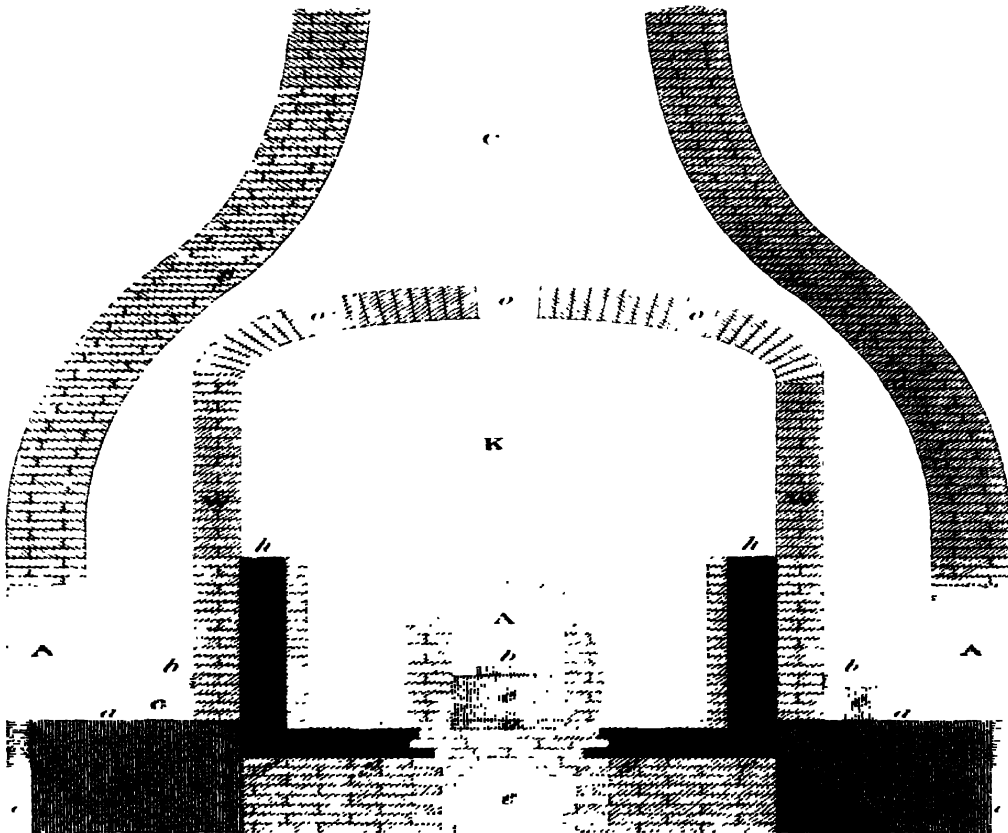
Cobridge, which is situated partly in the parish of Burslem, and partly in that of Stoke, is a very large and populous village, and possesses spacious manufactories "of the staple articles of the country earthen-ware in it."

Etruria is a large village, in which is a seat belonging to Josias Wedgewood, esq., who has the most extensive manufactory here of any in The Pottery. The name Etruria was bestowed upon it by the father of the present proprietor, whose inventions and discoveries have not only, as before mentioned, advanced his own particular art, but have contributed in a high degree to the enlargement of natural knowledge in general.

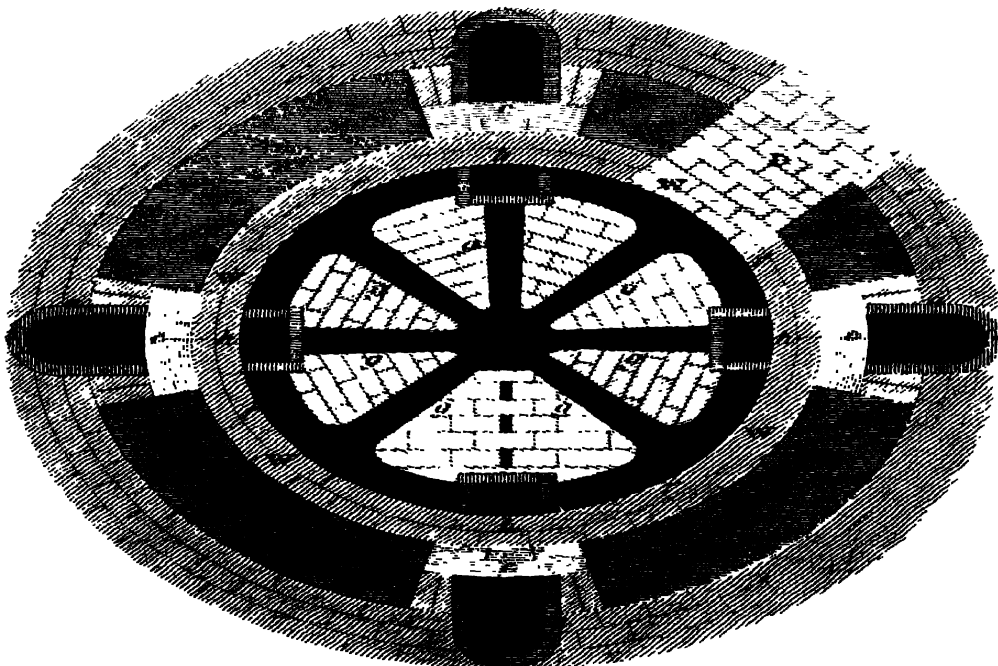
Lane-End, *Lower-Lane*, and *Lane-Delft* adjoin, and conclude The Pottery on its eastern boundary. The first mentioned of these townships is by far the most considerable of the three, containing, according to the returns for 1811, 1097 houses, and 4930 inhabitants. Here are a chapel of ease to Stoke, a Methodist chapel, and several meeting-houses for dissenters. Among the less important places in this district, where manufactories of earthen-ware are established, are New-Chapel, Wollstanton, Reddreet, and Norton, which are the most considerable. A Description of the Country from thirty to forty Miles round Manchester, by J. Aikin, M.D., 4to. Shaw's History, &c. of Staffordshire, fol. vol. 1.

POTTERY

Vertical Section.



Horizontal Section



Press

PRESS, a machine of most extensive use in the mechanic arts, for squeezing or compressing any substance very close, and also to retain the matter under the pressure as long as may be required.

All presses consist of the following parts: 1st, two flat, smooth tables of wood or metal, between which the substances to be pressed are placed; 2dly, the frame, or cheeks of wood or metal, which unite and retain the two together; and 3dly, the mechanical power, by which the pressure is effected. This is generally a screw, or two screws, turned by a long lever, or by wheelwork. At other times a rack is employed, and moved by a pinion turned by wheelwork, to give it a great power. Some presses used for expressing of oils are actuated by a wedge driven by a hammer or stamper, (see *OIL-Mill*), and in others, the pressure is produced by means of a powerful lever, and retained by a rack and click. Of late years the hydrostatic press has been produced, acting by the pressure of water or other fluids in cylinders. We shall now speak of the different kinds of presses.

Screw-presses are those in which the pressure is caused by means of one or more screws; the most common have a single screw, formed either of wood or iron, which at its lower end has a globe-head, with four holes through it, for the reception of the end of the lever employed to turn the screw; the thread of the screw is fitted through a nut, fixed fast in the head of the wood, or iron frame of the press. This frame consists of a lower bed, or horizontal piece, on which the matters to be pressed are laid, two upright cheeks being firmly united with it, and supporting the head, or upper horizontal piece of the press, in which the nut of the screw is fixed; the lower point of the screw is united with the follower, or moving bed of the press, and this rests upon the substances to be pressed, and the power of the screw forces it down upon it.

A drawing of this press, with its lever, and also a windlass to work it with immense power, will be found in *Plate XI. Agriculture*, as applied to express the juice of fruit for cider. The same kind is also employed for expressing some vegetable oils, but generally with iron framing, because of the great strength required; for packing cloth, paper, and other goods; also in the paper-mills, for flattening and rendering paper solid; and in the manufacture of woollen cloth, for glazing and setting a finish upon the article in its last stage.

Two elevations of a very good screw-press for a paper-mill are given in *figs. 6 and 7 of Plate II. Paper-Mill*. *A A* is the bed, formed of an immense beam of oak; and each of the cheeks, *B*, consists of a long iron bar *b b*, (*fig. 7.*), the ends of which are welded together, so that it forms a long link, one end of which receives the end of the bed *A*, and the other the end of a massive cast-iron cross bar or head *D*, through which the screw, *E*, is received, and its nut fixed fast therein. The open spaces of the long links or cheeks, *b, b*, are filled up by rails of wood, *C*, which support the weight of parts of the press when it is not in action, but these bear nothing, when the press has any articles under pressure in it; these articles are laid at *H*, on the bed, and the follower, *G*, is pressed upon them by the screw, when it is turned by a long lever put through the holes in the screw-head *F*. The screws employed for paper presses are generally formed with such coarse threads, and so rapid a spiral, that the elasticity of the paper is sufficient to force it to run back. To these a ratchet-wheel, *a*, is fixed, and a click, *c*, (*fig. 8.*) is applied to its teeth: to prevent its return, the click is supported on a bar *b d*, which moves on a cen-

tre at *B*, but the other end is retained by a catch or lever *f g*. When the press is to be relieved, the end, *f*, of the catch is driven back; this relieves the bar *d b*, and the click no longer detaining the ratchet-wheel, the screw runs back.

The screws for presses were formerly made of wood, with sharp threads, that is, the worm of the screw, if cut across, would make a triangular section, the base thereof abutting upon the cylinder of the screw. In this method it was necessary to have the threads very coarse, to give them sufficient strength, and then the power of the screw was not so great as in the modern presses, where the screws are made of iron, and their threads need not be above one-third or fourth the distance asunder, to have the same strength.

Another advantage of the iron screw is, that the friction is so much diminished, that a far greater pressure can be obtained by the same exertion of the people who work it. The frames of the modern presses are also made of iron, wood being found incapable of resisting the strain of a severe pressure, for any considerable length of time; as all the fibres, even of the hardest oak, become separated into ribbands, and then break one at a time, till the whole beam fails.

Another kind of screw-press consists of two screws, which are immovably fixed in the lower board or bed, and passing through holes in the upper board, have nuts upon them, which being turned by a lever, draw the two boards together, and exert a pressure upon any thing placed between them. Sometimes the screws pass through the upper board, and are tapped into the lower one; then the screws themselves are turned round by a lever put through their heads, instead of turning the nuts. Presses of this kind, when accurately made, have a communication of wheelwork from one screw to the other, so that both shall turn round together, and cause the two boards of the press to advance parallel to each other.

A very ingenious and useful packing press, invented by Mr. John Peek, was, in 1798, rewarded by the Society of Arts. This machine consists of two very strong horizontal beams, one at the bottom for the bed, and the other at the top of the press. These are united by two iron screws, which stand in a vertical position, and therefore serve as cheeks to the press. The follower of this press is a very strong horizontal beam, having two nuts fitted into it at its ends. These nuts act upon the threads of the two vertical screws; and, therefore, it is plain when they are turned round, the follower will rise and fall upon them. The nuts are so fitted into the follower, as to admit of a circular motion round the screws, but are not permitted to rise or fall without the follower, because they have a circular ring or projection in the middle of their length, which is fitted into a proper receptacle in the wood-work. To give them motion, the edges of the circular rings are cut into cogs or teeth, and are turned by means of an endless screw for each, situated at the opposite ends of a horizontal spindle, which revolves in bearings attached to the follower of the press. The spindle has a winch at each end, by turning which, the two endless screws act upon the wheels or teeth of the nuts; and by thus causing them to turn round with equal velocities, raises or depresses the follower, always parallel to itself, and also to the head and bottom bed.

The great utility of this press consists in its being capable of packing two sets of bales at once; thus answering the

purpose of two presses, and with more expedition. It is placed upon the floor of the warehouse in which the packing is to be performed, and behind it a stage is erected, just half the height of the whole press; then one set of the bales are made up on the floor, and the other upon the stage. Suppose the follower raised up above the level of the stage, a bale of goods is placed on the lower bed, and by turning the winches, the follower is forced down upon it, till it is sufficiently pressed: now, while the men below are tying and making the bale fast, the people on the stage place a bale upon the follower; and it is plain, that when the follower is raised up to relieve the lower package, the upper bale will be compressed between the follower and the head of the press; and while this is making fast, the workmen below get another bale of goods loaded in. By this means no time is ever lost in screwing up or opening the press; for it performs work both ways, which is a matter of no small importance in large works, such as the East India Company's warehouses, where such a great number of people are employed in packing.

In the Philosophical Transactions for 1781 is an account of a double screw, applied to a press, by Mr. W. Hunter. To explain this, we must suppose a single screw-press of the ordinary form, such as shewn in *Plate XI. Agriculture*, or *Plate II. Paper-Mill*; but the lower end of the screw, which rests upon the follower or presser, has a second screw of finer thread cut upon it. This thread is received into a nut or barrel, which rests upon the presser. The nut is at liberty to turn round freely upon the presser, except when it is required to be stationary; and then, by a key, it can be fixed fast to it. In like manner, the nut or barrel can, at pleasure, be fixed fast to the lower screw by a key put through a hole in both; and in this state they will of course turn round together. As the nut and lower screw take up some room, the screw is turned by arms fixed in a head, formed on the upper end of it, above the press. In the operation of this press, the nut or barrel is pinned fast to the lower screw by the key; and the screw being turned by the arms at top, the nut is carried round with it, and the effect is exactly the same as an ordinary screw-press. But having by this means given as great a pressure as the single screw is capable of producing, the cross key which unites the lower screw to the barrel is removed, and is put in such a position, that it unites the barrel to the presser, so as to prevent its turning round upon it. The effect of the press now becomes compound, and while the whole screw is carried downwards by the revolution of the great screw, the fine screw at the bottom of it screws down into the barrel or nut, which is attached to the presser; which is, therefore, carried down a quantity only equal to the difference of the thread of the two screws; and if these are made very nearly alike, the descent produced by the difference between them will be exceedingly small, and the power exerted upon the articles under pressure will be in proportion to it. Indeed the effect would be the same, as if a single screw had been employed, having its threads so fine or close together, that the difference between thread and thread is only equal to the difference between the measures of the threads of the two screws.

For example: Suppose it was required to produce a strong pressure, with a screw of ten threads in an inch, it is evident that the metallic protuberance, or helix of the screw, could not be quite so thick as one-twentieth of an inch, and could not, therefore, withstand any considerable force. By the present construction, we may have the thread as strong as can be desired. Thus, if the slightest be a quarter of

an inch, the finest screw must have two turns in the inch, and the coarsest two turns in one inch and one-tenth; or, in other words, it would pass over the same space in ten turns, that the other screw would in eleven.

Upon the invention of the double screw Mr. Nicholson remarks, that from the extreme precision of a simple screw, if commonly well made, it may seem scarcely necessary to use this contrivance in the measurement of small quantities. The finest screws usually to be met with do not exceed 100 threads in the inch, and few have been made finer than of 200 threads in that space. Let us consider by what threads, of usual, or even coarse numbers, we could have a difference *per* turn of above one-thousandth of an inch, and we shall find that the difference between a thread of 32 and one of 33 in the inch, is the 1056th part of an inch; so likewise, the difference between the 60th and 61st parts of an inch is the 3660th part.

The *Hydrostatic* or *Water Press* has, for a great number of purposes, superseded the use of the screw-press, over which it possesses great advantages, in all cases where a strong pressure is required. This machine was invented by Mr. Joseph Bramah, and its principle has been explained in our article *MACHINERY*. (See vol. xxi.) In plate *Press* we have given drawings of one of them, *figs. 1 and 2* being elevations, taken in opposite directions; *A A B C C* is the frame, consisting of a piece of cast iron, *c c*, (see also *fig. 3.*), and a top piece of cast iron, *B*, (see also *fig. 4.*), the two being united by the wrought iron bolts *A, A*, which must have sufficient strength to resist the whole force of the press, the pressure being produced between the under surface of *B*, and the upper surface of an iron table or follower, *E*; *F* is a strong metallic cylinder, in which the rammer or piston, *D*, moves. To the upper part of this piston, the iron table, *E*, is fixed, by the motion of which upwards, the pressure is communicated to the articles placed upon it; *L* represents a cistern containing water; within this cistern is fixed a small forcing or injecting pump, of which *b* is the piston rod, and *H* the lever by which it is worked, a contrivance being introduced for keeping the piston rod vertical during the working: it consists of a guide, formed at the top, of the same standard, *K*, which supports the fulcrum or centre pin, *e*, of the lever *H*; the rod *g*, which is part of the piston rod, slides through the socket; the part, *f*, of the rod is made open, to admit the lever to pass through it, a link being applied to unite the lever to the rod; *I* is a counterbalance for the weight of the lever. *Fig. 5.* is a section of the pump, on a larger scale, to shew its interior structure, *b* representing the lower extremity of the piston rod; it is surrounded by a collar of leather, *s*, which is retained in its place by a tube, or perforated screw, *r*, which admits the passage of the piston rod *b*, but which screws the two-cupped leathers with the metal ring, which is interposed between them, close down to a shoulder, in the body of the injecting pump, and thus renders the junction between the injecting piston *b*, and its cylinder, water-tight: the upper part of the screw, *r*, is excavated, to form a receptacle for oil; *M M* is the barrel, or chamber of the pump, in which the piston rod does not fit; but the collar of leather *s*, closely embracing the rod, will have the same effect of enlarging or diminishing the capacity of the chamber when the rod is moved up and down. In the bottom of the chamber is a suction valve, *N*, which allows the water to enter into the barrel from the cistern, but will not permit it to return in the same direction; it is fitted into the upper part of a tube, *N*, which is screwed into the lower end of the barrel: the valve itself

consists of a metallic rod, at one end of which there is a knob turned conical next the stem, so as accurately to fit the conical face of the hole into which it is put; the tail is filed on one side, so that it does not entirely fill the cylindrical hole which it occupies, by which means a passage is afforded for water when the head of the valve is raised. A valve of a similar nature is placed at *t*, in the upper part of the pump, and being in the passage which conveys the water from the pump, and through the copper pipe, *b*, to the cylinder, *F*, it allows the water to pass from the pump to the cylinder, and prevents its returning. At *k*, *fig. 5*, is a safety-valve, which is loaded by a steelyard and weight, as shewn at *k*, *fig. 1*: this keeps the valve shut in the ordinary course of working; but if the pressure should become so great as to endanger the bursting of the pipes, the valve rises, and the water escapes. At *i* is a screw plug, or valve, at which the water is discharged, when the press is to be relieved. When screwed tight, its conical end or point is forced into a corresponding socket, and prevents the escape of the water; but on turning the screw back, the water is permitted to flow back into the cistern. The real situation of this discharging valve is shewn in *fig. 1*, at *i*. The cylinder, *D*, is surrounded by a collar of leather at *o o*; the leather is formed as shewn in *fig. 7*, being turned up to form a double cup, so that it resembles the cuff of a coat sleeve. When in its place it is kept distended by the copper ring, *p*, entering the circular channel, or fold, of the leather. This ring has a lodgment in a recess formed within the cylinder *F*. The leather is kept down by a brass or bell-metal ring, *m*, which is received into a recess formed round within the cylinder, as shewn in *fig. 5*. The interior aperture of this ring is adapted to receive the cylinder *D*, and thus the leather becomes confined in a cell, with the edge of the interior fold applied to the cylinder *D*, whilst the edge of the outer fold is in contact with the interior surface of the cylinder *F*. In this situation the pressure of the water, acting between the folds of the leather, forces its edges into close contact with both, and makes a tight fitting round the cylinder, and as the pressure is increased the leather is applied more closely, so as to prevent leakage under any circumstances. The metal ring, *m*, is truly turned in the lathe, and the cavity or cell formed for its reception; then to get it into its place, it is divided by a saw into five segments, as shewn in *fig. 6*. Three of the lines at which it is divided point to the centre, but the other two are parallel to each other, and the ring is put into its place (after the leather and copper rings are introduced), by putting in the four segments separately, and the one with parallel sides is put in last. The cylinder, *D*, is then put down in its place, and ready for action. This plan of a divided ring was first used by Mr. Peter Kier, who, since the expiration of Mr. Bramah's patent, has made several hydrostatic presses. In the original construction, the ring or head of the cylinder, which kept down the leather cup, was held down in its place by several screw bolts, but as these had to bear a greater force than the whole power of the press, they were frequently torn out, or strained, so as to cause leakage. The upper part of the cylinder above the ring, *m*, is filled with tow, or other soft packing, impregnated with sweet oil, which is confined by a thin plate or ring. This packing serves at once to supply the cylinder with oil, and to prevent the admission of any substance which might injure the surface of the piston.

The pipe, *b*, is made of copper, and its joints are made as shewn in *fig. 5*. The end of the pipe has a projecting piece folded or screwed upon it, and this fits into a cavity formed in the metal of the pump or cylinder, and it is forcibly

pressed into its seat by a perforated screw *w*, which screws into the cavity. The joints are rendered tight by a leather ring or washer, interposed between the end of the pipe and the bottom of the cavity in the cylinder or pump.

The hydrostatic press is not liable to get out of order, but if any extraneous matter attaches itself to either of the valves, their action will necessarily be suspended till it be removed; for this purpose the valves can be taken out. The valve at *t* has a screw plug, *g*, fitted over it, and this regulates the ascent of the valve, or by unscrewing the plug the valve can be taken out. To get access to the lower valve, the lower piece, *N*, of the pump must be unscrewed. The discharging valve, *i*, may also be examined by withdrawing its screw.

The operation of this press may be very readily comprehended, by supposing the pump, cylinder, and connecting pipe *b*, to be filled with water, and that an adequate supply of water is contained in the cistern *L*. When the handle of the lever, *H*, is raised, it brings up the piston *b*, which would leave a vacuum beneath, if the atmosphere did not force the water through the lower, or suction valve, of the pump. The lever being then pressed down, the piston rod, by descending, diminishes the capacity of the pump; this causes the lower valve to shut, and forces the water through the valve *t*, whence it passes, by the pipe *b*, into the cavity of the great cylinder *F*, and raises the piston *D*, and pressurizable *E*, together with its load, a distance proportioned to the quantity of fluid injected. On the subsequent rise of the piston of the pump, the descent of the upper valve prevents the return of the water, and consequently the fall of the cylinder *D*. A repetition of the same process injects more water, and the pressure may, in this manner, be carried to a great extent. When it is proposed to relieve the action of the press, the discharge valve, *i*, must be opened by turning the screw back; the water then escapes out of the press into the cistern *L*, and consequently the table *E*, and the cylinder *D*, descend by their own weight, restoring the engine to its original situation.

The mechanical effect of the hydrostatic press will admit of an easy calculation. For it is known, that if there be a mutual communication between two columns of any fluid, whatever pressure or effort may be exerted on the one, will be transmitted to the other in a ratio proportional to the respective area of each column, consequently the proportion of the area of the injecting pump to that of the cylinder constitutes the hydrostatic power of the press, and the mechanical effort exerted on the injecting pump is transmitted to the cylinder *D*, by the intervention of the fluid, in a ratio proportional to their comparative areas.

If the diameter of the piston, *b*, be one quarter of an inch, and that of *D* one inch, that is to say, four quarters of an inch, one pound lodged upon the piston rod, *g*, will be in equilibrio with sixteen pounds lodged upon the table *E*, the weights of the parts of the engine attached to, and moving with each piston, being respectively included. And if the length of the lever, *e H*, be fifteen inches, and the distance between the centres of motion, *e f*, of their action upon the piston rod two inches, one pound at the end of *H* will gain an advantage of $7\frac{1}{2}$ times, when compared with that at *g*. Instead, therefore, of sixteen pounds, upon the table *E*, being equal in effect to counterpoise this last action, there will be required upwards of 120 pounds. But a man in this action of pumping, by a downward pressure, can, without difficulty, apply his whole weight, and with great ease one-third, or one-fourth, of his weight, suppose 50 pounds. In this case the pressure will be equivalent to 50 times 120 pounds, or 6000 pounds, that is to say, nearly three tons.

To compare this engine with a screw in theory, we must enquire what fineness of thread, and length of lever, would afford a purchase of 120 to 1. Let us suppose the thread of a screw, substituted in the place of the cylinder D, to be one-tenth of an inch thick, the distance from the top of one thread to the top of the next, will in this case be one-fifth of an inch. This is the space through which the weight must rise in one revolution of the screw; the power must, therefore, move through 120 times that space, namely, twenty-four inches. A lever or radius four inches long will describe a circle somewhat larger than this, and consequently such an engine would, in theory, be equal in power to the hydrostatic engine we have been describing.

But when the subject is viewed practically, the difference between the two machines appears to be very remarkable. All practical men know how very large a part of the force, operating by means of engines, is employed in overcoming friction. Every one is aware of the extreme friction between solids, and the very slight friction which takes place between the parts of fluids. This is seen in the common expedient of oiling the pivots of wheels, and in the very gradual decay of motion in fluid bodies, while solids moving upon each other stop at once as soon as the force is diminished to a certain degree. The screw is an organ peculiarly liable to friction, and this friction is always much greater than the whole of the re-acting force, for there are few instances where a screw will return from extreme pressure, when the agency upon the lever is withdrawn. It is also to be considered, that the whole force of the weight or resistance acts directly upon the face of the thread of the screw, at the place where the motion is required to take place. It has not been ascertained in what degree this resistance or friction increases with the weight. In lighter actions the simple ratio has been inferred, but under more severe pressures, the two metallic faces exclude the greater part of the half fluid matter between them, and appear, by the magnitude of their resistance, to be attached to each other by a process of the nature of cohesive attraction.

Mr. Nicholson, in his Journal, relates the following experiments, which he made with one of Mr. Bramah's small presses, which he makes for the purpose of copying letters, or writings, in the manner of Mr. Watt (see COPYING); it had the same parts which we have described, but the frame made of wood. When employed to press papers, the force applied to the lever of the injecting pump was so slight, that the instrument required no fastening to the table on which it stood; but the effect of the upper bar, B, which was of wood, three inches and a half thick, was such, as bended it out of a straight line upwards of a quarter of an inch, and it appeared that it might have easily been broken by continuing the pressure. With a screw-press, the screw of which was iron, and nearly of the dimensions above mentioned, excepting that the lever was twelve inches long instead of four inches, and the action on the lever upwards of two hundred weight, applied with a jerk, the effect was nearly the same: he estimated the advantage to be very much in favour of the hydrostatic press.

In another press of this kind, the diameter of the great piston was four inches, and of the smaller three-eighths of an inch, and the advantage given by the lever or handle was twelve to one. Above the piston, D, of the great cylinder, was applied a long lever, at one end of which was an axis, and at the other end a large scale to hold weights; it contained twenty hundred weight. The distance between the axis of motion of this lever, and the part where it acted on the piston, was six inches; and the distance from the same axis to the extremity where the scale was hung, was one

hundred and twenty-six inches. Every hundred weight in the scale consequently pressed upon the piston with a force equal to twenty-one hundred weight, whence the whole pressure was twenty-one tons. It was easy to work the lever briskly with one hand, and each stroke raised the scale nearly one-third of an inch. Forty-seven pounds, hung at the end of the lever, carried it down with a moderate swiftness of working; but a weight of only forty-three pounds remained in equilibrio, and did not descend. Now as the true weight in theory was thirty-two pounds, as deduced from the dimension of the parts in the manner already done, with regard to the small press it follows, that less than one-third of the actual power was employed to give velocity, and overcome all friction.

It may be remarked, that the principal frictions in these presses must be at the circumference of the pistons, and that these do not increase in the simple, but in less than the sub-duplicate ratio of the power. For if the diameter of the great cylinder were double, every thing else remaining unchanged, the surface of its piston, and consequently the power, would be quadrupled, but the friction would be only doubled, and that merely at the leathering of the greater piston D.

As the pressure, in the experiment last mentioned, amounted to forty-seven thousand and forty pounds upon the great piston, of four inches diameter, and sixteen circular inches surface, it amounted to two thousand nine hundred and forty upon each round inch; but the medium pressure of the atmosphere on a round inch is nearly twelve pounds, consequently the action was equal to two hundred and forty-five atmospheres, and as each of these corresponds with a column of thirty-four feet of fresh water, at a medium the water in the cylinder was pressed in the same manner, as if the whole column had been eight thousand three hundred and thirty feet, or one mile and two-thirds perpendicular height.

Large presses of this construction are generally made with two pumps, of one inch and a quarter bore, and a cylinder of seven inches. These have been used in pressing hay and cotton for package, and are very effective in producing a greater condensation on the material, with a much less application of moving power, and consumption of time.

Presses used for expressing of liquors, are of various kinds; some, in most respects, the same with the common presses, excepting that the under plank is perforated with a great number of holes, to let the juice expressed run through into a tub, or receiver, underneath.

Others have only one screw, or arbor, which passes through the middle of the moveable plank, which is made to descend into a kind of square box, full of holes on all sides; through which the juices flow, in proportion as the arbor is turned; by means of a little lever applied thereto.

Press used by joiners to keep close the pieces they have glued, especially pannels, &c. of wainscot, is very simple, consisting of four members; viz. two screws, and two pieces of wood, four or five inches square, and two or three feet long; of which the holes at the two ends serve for nuts to two screws.

Press used by inlayers resembles the joiners' press, except that the pieces of wood are thicker, and that only one of them is moveable; the other, which is in form of a tressell, being sustained by two legs, or pillars, jointed into it at each end.

This press serves them for sawing and cleaving the pieces of wood required in marquetry, or inlaid work.

PRESS, Founders', is a strong, square frame, consisting of four pieces of wood, firmly joined together with tenons, &c.

This press is of various sizes, according to the sizes of the moulds; two of them are required to each mould, at the two extremities of which they are placed; so as that, by driving wooden wedges between the mould and the sides of the presses, the two parts of the mould, in which the metal is to be run, may be pressed close together.

PRESS, Printing. See **PRINTING Press**.

PRESS, Messenger of the. See **MESSENGER**.

PRESS, Auditors of the. See **AUDITORS**.

PRESS, Rolling, is a machine for the taking off prints from copper-plates.

It is much less complex than that of the letter-printers.

See its description and use under the article *Rolling-press*.

PRINTING.

PRESS, in Coining, is one of the machines used in striking of money; differing from the balance, in that it has only one iron bar to give it motion, and presses the moulds, or coins; is not charged with lead at its extreme, nor drawn by cordage. See **COINAGE**.

PRESS, Binders cutting, is a machine used equally by book-binders, stationers, and pasteboard-makers; consisting of two large pieces of wood, in form of cheeks, connected by two strong wooden screws; which being turned by an iron bar, draw together, or set asunder, the cheeks, as much as is necessary, for the putting in the books, or paper, to be cut.

The cheeks are placed lengthways on a wooden stand, in form of a chest, into which the cuttings fall. Aside of the cheeks are two pieces of wood, of the same length with the screws, serving to direct the cheeks, and prevent their opening unqually.

Upon the cheeks the plough moves, to which the cutting-knife is fastened by a screw; which has its key to dismount it, on occasion to be sharpened.

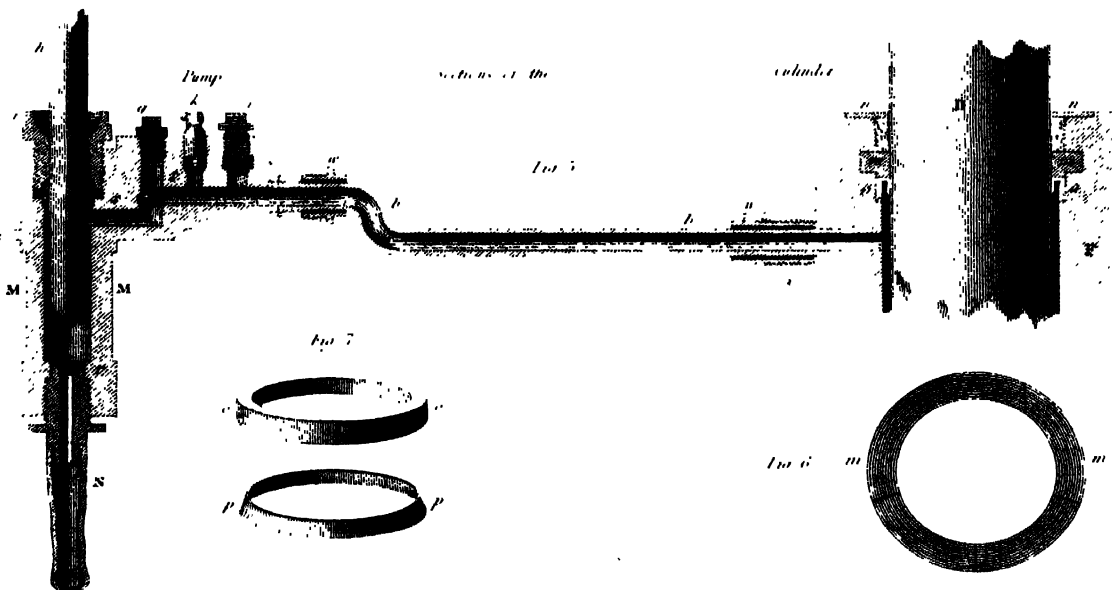
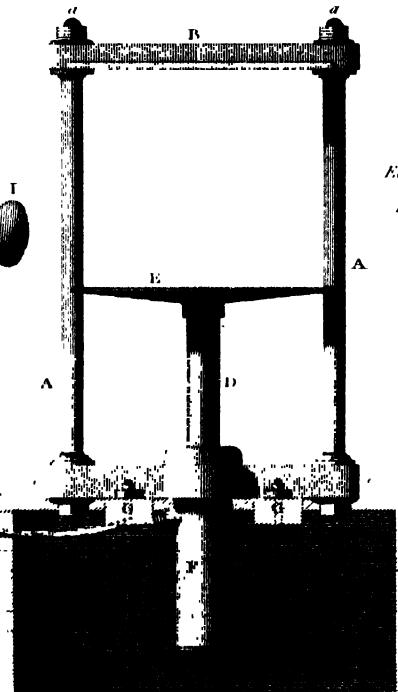
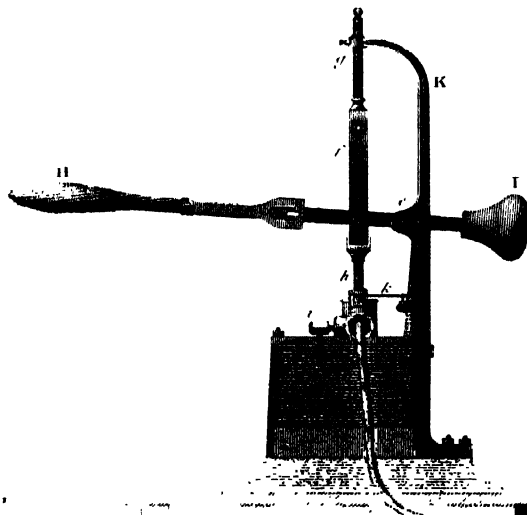
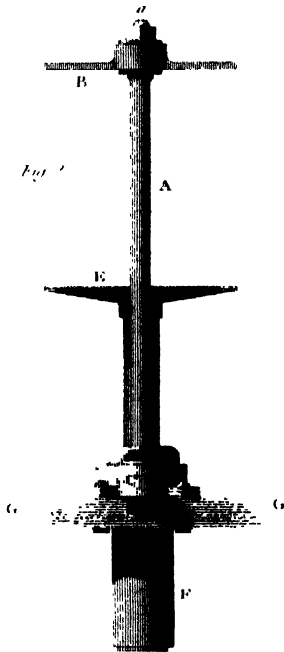
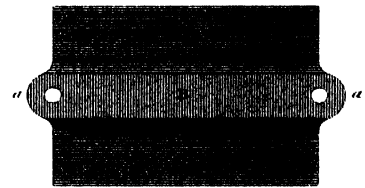
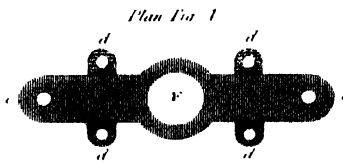
The plough consists of several parts; among the rest, a wooden screw, or worm, which catching within the nuts of the two feet, that sustain it on the cheeks, brings the knife to the book, or paper, which is fastened in the press between two boards. This screw, which is pretty long, has two directors, which resemble those of the screws of the press. To make the plough slide square and even on the cheeks, so that the knife may make an equal paring, that foot of the plough where the knife is not fixed, slides in a kind of groove, fastened along one of the cheeks. Lastly, the knife is a piece of steel, six or seven inches long, flat, thin, and sharp, terminating at one end in a point, like that of a sword, and at the other in a square form, which serves to fasten it to the plough. See **BOOK-BINDING**.

As the long knives used by us in the cutting of books or papers are apt to jump in the cutting thick books, the Dutch are said to use circular knives with an edge all round; which not only cut more steadily, but last longer without grinding.

PRESS, in the Woollen Manufactory, is a large wooden machine, serving to press cloths, serges, rateens, &c. by which to render them smooth and even, and to give them a gloss.

This machine consists of several members; the principal of which are the cheeks, the nut, and the worm or-screw, accompanied with its bar; which serves to turn it round, and make it descend perpendicularly on the middle of a thick wooden plank, under which the stuffs to be pressed are placed. The calender is also a kind of press, serving to press or calender lincos, silks, &c.

Plan Fig. 3.



Pressure engine

PRESSURE Engine is an hydraulic machine, acting by the power of a descending column of water upon the piston of a cylinder, to give motion to pumps, for raising water from a different level. In the mountainous districts which so frequently contain rich mineral treasures, falls of water may be often obtained at a greater elevation than it is practicable to construct water-wheels of sufficient size to occupy the whole descent; and often the stream is too small to supply a wheel. In these situations the pressure engine is well adapted to produce the greatest effect from the fall, in working pumps, or other machines for draining the mines of water. The same principle can readily be extended to the raising of water for supplying towns, gentlemen's houses, &c.; and universally for raising water from any depth wherever a fall of water can be procured, particularly in those cases where the fall is great, that is, where it exceeds 30 or 40 feet. It will not only exceed all other known machines in effect, but in simplicity, and that whether the quantity of water that is to be applied is great or small.

Machines of this kind, invented by Mr. Denizart, are described in the *Machines Approuvées par l'Académie* for 1731, vol. v. and by Mr. Genlis in 1741, vol. vii.; but the earliest which was put in execution in this country was by Mr. William Westgarth, who invented the proper expedients to obviate those difficulties which had before attended the practical execution of machines upon this principle in France; he erected a large one at a lead mine of Sir Walter Blackett's, at Coal Cleugh, in Northumberland, in the year 1765. Mr. Westgarth's machine consisted of a cylinder, provided with a piston suspended by a chain from a beam or working lever, from the opposite end of which the rod of the pump, which was to raise the water, was suspended; the working cylinder was made the full height of the column of water which was employed to work the engine, and the working beam was, of course, placed above the top of it, whilst the chain and rod reached down into it; so that the piston itself acted in a chamber or barrel, nearly at the bottom of it; a trough, or cistern, at the top of the cylinder, was kept constantly supplied by the stream of water, and thus the whole height of the cylinder being filled with water, the pressure of its column always bore upon the piston. From the lower part of the cylinder was a passage to permit the water to escape from it, and likewise another passage by a pipe, communicating from the lower part of the cylinder, beneath the piston, to the upper part of the same above the piston. Both these passages were governed by a sliding valve of very ingenious structure, which opened and shut them alternately, but would not allow both to be open at one time. The sliding valve was actuated by an apparatus of levers, very similar to those used in the old steam-engines for opening the cocks; and the pump rods were so loaded as always to have a preponderance to draw the piston up when the pressure of the water upon it was removed or balanced. Suppose the piston at the top of its motion, by opening the passage from the bottom of the cylinder the water escapes from it, and relieves the lower side of the piston from the pressure of the water, whilst the whole column continues to press upon the upper side: in this situation the piston descends, drawing up a column of water in the pumps at the opposite end of the beam or lever, but on arriving at the bottom of the cylinder, the mechanism alters the sliding valve, and it closes the passage at which the water escapes from the cylinder, and at the same time opens the other in

the pipe, which admitting the water from the upper into the lower part of the cylinder, it will press equally below the piston as above it, consequently the forces are balanced, and the counter-weight of the pump rods, at the opposite end of the beam, will draw up the piston to the top of its chamber, when the position of the sliding valve is again altered, and it closes the pipe, at the same time opening the passage for the water to escape; this makes another stroke, and thus the engine continues to work as long as the supply of water is kept up. The minutiae of the machine are described in the *Transactions of the Society of Arts*, vol. i. but the ingenious Mr. Smeaton soon improved it very materially, by enclosing the top of the cylinder with a lid, through which the piston rod passes in a collar of leather, and the cylinder is then required to be no higher than convenient for the motion of the piston within it, the water being introduced to it by a pipe. The construction of Mr. Westgarth's sliding valve he preserved with very little alteration. In *Plate Pressure*, we have given drawings of a small engine which Mr. Smeaton erected in Yorkshire, at the seat of Lord Irwin, in 1770, to raise a supply of water for the service of the house. *Figs. 1 and 2* are elevations of the whole engine, and the other figures are enlarged sections of the sliding valve, which regulates the admission of the water into the working cylinder at proper intervals, to cause the motion.

The pipe, A, which supplies the engine with water is 1.7 of an inch bore; its perpendicular descent from its mouth or entry at the spring of supply is 54 feet; and its length 400 feet. The water is conveyed from the engine by a pipe, I, which has a fall or descent of twelve feet from the engine to the surface of the water in the pit or well into which it delivers; and it has a stop-cock, which regulates the discharge of the water. This descending column of 66 feet of water is employed in working a pump, D, which throws back part of the water to a reservoir by a pipe, O, in ascent about 900 feet in length, and 1.5 inch bore. The delivery of this pipe at the top of the reservoir is 80 feet above the engine, consequently 26 feet above the level of the head or spring of supply. The pipe, A, conducts the water to the pump, D, by one branch, and to the top of the cylinder, C, which works the engine, by the other. The cylinder, C, is of brass, truly bored, and furnished with a solid piston, whose rod, b, passes through a close stuffing-box in the cylinder lid, where a leather is packed round it so closely, that no water can leak by it; the upper end of the piston rod is keyed into a small box, which connects it with an iron rod, sliding through a guide, c, to make it move steadily. K is the working-beam, moving round a centre at L; it has an arch head at the outer end, which is a segment of a circle, struck from the centre L; the arch receives a chain, by which the piston-rod, b, is suspended, and therefore has a vertical motion. E is the pump-rod, jointed to the beam, and moving up and down with it; the forcer of the pump, D, is fixed to it at the lower end. H is a pipe, which forms a communication between the top and bottom of the cylinder; it leads down into a chest, N, upon which the cylinder is placed, and to which it is open at bottom; the chest is composed of plates screwed together, as shewn by the sections, *figs. 3, 4, and 5*, which also explain the construction of the sliding valve contained within the chest. In these figures, s is a short cylindrical pipe, fixed across within this chest, and communicating with the

pipe, H, at top, and the pipe I (which conveys the water away from the engine) at bottom. This short pipe has a water-tight division, *v*, (*fig. 4*.) in the middle of it, so that there is no direct passage through it from H to I; but there are four square holes made in the pipe, at equal distances round it, above and also below the division, as shewn at *figs. 4* and *5*. A cylinder or tube of brass, *t t*, is fitted upon the cylindric pipe, and slides up and down it, being packed with leather round the edges of the middle partition, as shewn in *fig. 4*, that no water may escape between the two cylinders. The sliding cylinder, *t*, is just half the length of the other, and when it is pushed down, as in the figures, it covers and stops the four holes in the pipe *s*, which are below the division *v*, and opens the four holes above the division, allowing a passage from the pipe H to the bottom of the cylinder C, *fig. 1*. On the contrary, when the slider is pushed up, the upper holes are closed, and the lower ones opened, making a passage from the cylinder bottom into I. The sliding valve *s*, besides the leather packing which furrounds the partition *v*, has leather placed at top and bottom of the fixed cylinder *s*, at *r, r*, and the ends of the slider are pressed upon these leathers, to make a tight joint when up or down, but the cylinder fits as tight as it can be made, independent of the leathers. The sliding valve has a pin projecting from each side of it, which pins are included between clefts made at the end of a forked lever *w x*, moveable on an axis *y*, which passes through the side of the chest in a collar of leather *z*, *fig. 5*, and has a long lever *o*, *figs. 1* and *2*, fastened upon it. By moving the upper end of this lever towards the engine, the sliding valve will be raised up; and by moving it in a contrary direction, the valve will be pushed down: *g* is a small iron rod, jointed to the upper end of the long lever by one of its ends, and the other is suspended by hooks from a spindle turning upon pivots, supported by the framing; this spindle has several levers upon it, similar to the working gear of a steam-engine, as follows: *b b e* is a three-armed lever; the arm, *e*, has a weight at the end, and is called the tumbling bob; *b* and *b* are two other arms, made in the same piece with *e*; these two latter arms strike against a pin, fixed across in the end of the rod *g*, which is forked, to admit the pin and the arms *b, b*, to act within the fork; *k* are two crooked levers, by which the spindle is moved as handles; these levers are struck by pins, *i*, fixed in a wooden rod *d d*, which is jointed to the working-beam K, and moves up and down with it: *c*, (*fig. 2*.) is a piece of wood fixed to the upright beams of the frame, having pins projecting from it, which catch the tumbling bob *e*, and prevent it moving too far; Q is a stop-cock in the main pipe, which regulates the quantity of water coming to the engine, and consequently the velocity with which the engine will work.

To describe the operation of the engine; suppose every thing to be in the position of the figures, and the pipes, cylinder, and pump, full of water, the sliding valve is down in the position of *fig. 4*, and therefore forms a communication from the top to the bottom of the cylinder: in this state the pressure of the descending column of fifty-four feet of water presses equally upon both sides of the piston of the cylinder, and therefore has no operation either way, the communication with the pipe I being stopped, so that the water cannot escape through it; but the pressure operates upon the lower surface of the forcer D of the pump, rising freely through the lower valve of the pump; this pressure, being unbalanced, raises up the working beam, and with it the piston of the cylinder and the rod *d*. This, as before mentioned, has pins, *i*, in it, one of which is seen, in *fig. 1*, to be just meeting the arm or handle *k*, which it raises, lifting

the tumbling bob *e*, and turning the axis with all its levers. When the engine arrives at the top of the stroke, the tumbling bob passes the vertical point, and falls over on the other side of the centre; the arm *b* now strikes the cross pin in the end of the rod *g*, and by drawing it moves the lever *o*, and lifts up the sliding valve; this closes the communication between the top and bottom of the cylinder, and opens a passage to the pipe I, permitting the water to pass through the pipe into the well, and thus get away from the engine. This removes the pressure of fifty-four feet from beneath the piston, though it still remains acting at the top of the piston, and has added to it the twelve feet from the engine to the bottom of the well, in consequence of this column being suspended in the pipe I; this unbalanced pressure causes the piston to descend, bringing down the end of the beam K, and pump rod E with it: the valve in the bottom of the pump now shuts, and the water in the pump, being pressed by the forcer, opens the other valve at M, and goes up the pipe, *o*, to the reservoir, lifting a column of water of eighty feet. When the engine gets to the middle of its stroke, a pin in the other side of the wooden rod *d*, and therefore not seen, takes the lever, *k*, and forces it down, raising the tumbling bob, *e*, at the same time. By the time the piston arrives at the bottom of the cylinder, the tumbling bob is brought past the vertical position, and suddenly oversets, by its own weight, into the position of *fig. 1*. The lever, *b*, now runs against the pin, across the end of the rod *g*, and shoves it from the engine, moving the long lever, *o*, of the sliding valve, and the short lever, *w x*, (*fig. 3*.) down, just in the position of the drawings. This closes the four lower holes in the fixed cylinder, and prevents the water going down the pipe I, but at the same instant opens the four upper holes, forming a communication between the top and bottom of the cylinder. The pressure of sixty-six feet, which caused the piston to descend, is now removed, or rather balanced, by causing it to act equal beneath the piston; and the column of water of fifty-four feet, coming down the pipe A, and through the branch, forces open the lower valve of the pump, (the valve at M closing and supporting the column of eighty feet,) presses the under side of the pump forcer, and raises it up, as before described, moving the beam and piston with it; there now being an equal pressure, both above and below the piston, it will be moved up easily. When the piston arrives at the middle of its stroke, the preceding operations are repeated; thus the pin in the rod, *d*, takes the lever *k*, and raises it till it arrives at the top of its stroke, when it again passes the vertical position, and instantly falls over into the position first described; the lever *b*, taking the end of the rod *g*, and pushing it towards the engine, raises the sliding valve, opens the passage to the pipe I, and the whole column of sixty-six feet now presses upon the piston, and forces it down as before described, overcoming a column of eighty feet upon the pump. Though the diameter of the pump is larger than that of the cylinder, this happens from the chain of the piston acting upon a much longer lever than the pump. P and N are two air-vessels upon the pipes A and *o*, to equalize the action of the pump, and to prevent the shock which would otherwise take place when the sliding valve was suddenly shut, and the motion of the descending water thus checked.

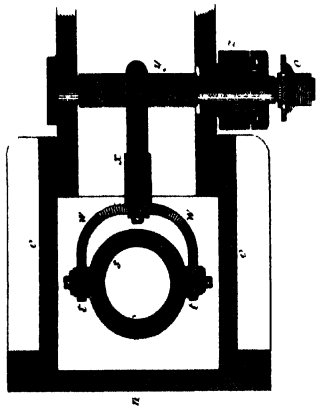
A very complete pressure engine was erected by Mr. Trevathick at the Druid copper-mine, in Illogan, near Truro, in Cornwall; it acted with a double power, that is, the pressure was first applied to one side of the piston to force it up, and then on the other to force it down, in the same manner as a double acting steam-engine. It acted by two sliding valves instead of one, but they were so made that one

opened rather before the other shut, and this, though it prevented the concussion of stopping the column of water, waited a small quantity of water, by permitting it to escape, which indeed is always in motion.

PRESSURE.

Mr. Smeaton's Water-pressure Engine.

Fig 3 Plan



*Fig 4.
Section of the Valve*

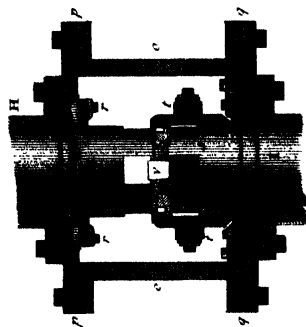
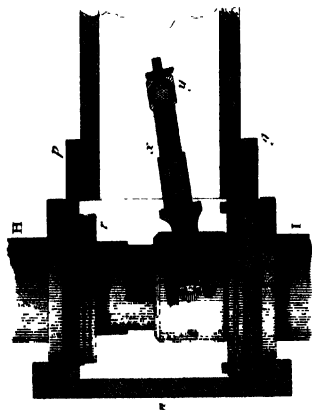


Fig 5. Section



Front Elevation

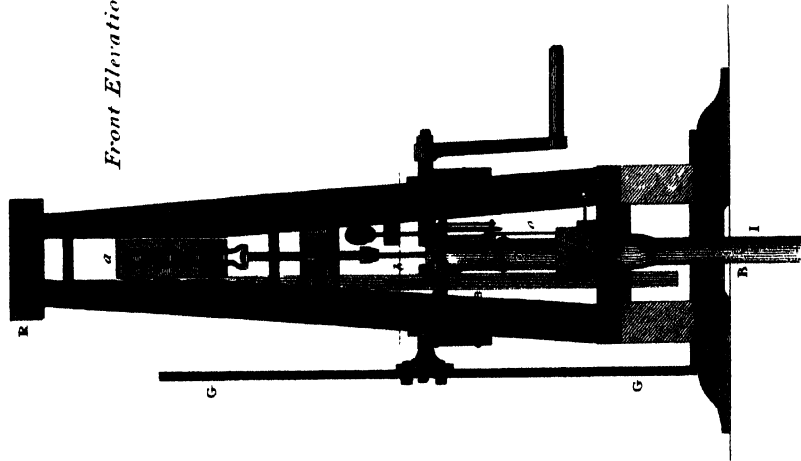
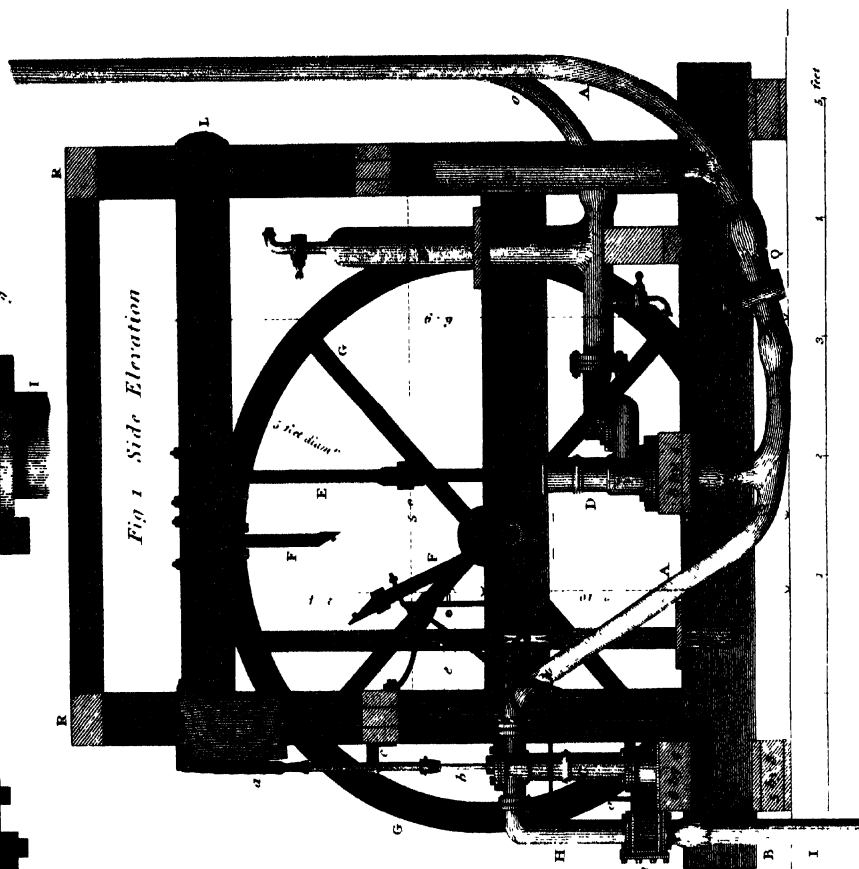


Fig 1 Side Elevation



Printing

PRINTING, 'TYPOGRAPHIA, the art of taking impressions with ink, from characters and figures, moveable or immoveable, upon paper, vellum, or the like matter.

There are two kinds of printing ; the one for books, the other from copper-plates, for pictures. The first called *common press printing*, the second *rolling press printing*.

The prime difference between the two consists in this, that the characters of the former are cast in relievo, and those of the latter are engraven in creux.

The art of printing is a modern invention : it is, indeed, of a very ancient standing among the Chinese ; but then their printing is very different from our's. It must be owned, the European printing, in its original, was much the same with the Chinese ; yet, as there was at that time no commerce or correspondence between Europe and China, the passage into the East by the Cape of Good Hope being as yet undiscovered by the Portuguese, there is no room to charge the Europeans with borrowing their art from the Chinese : but each must be owned to have fallen on the same thing, though at very different times. Father Couplet assures us, that printing has been in use in China from the year 930. Father le Compte speaks more largely ; saying, that it has been there from almost all ages : he adds,

that there is this difference between their's and our's, that whereas we have but a very small number of letters in our alphabets, and by the various arrangement of these, are able to form infinite volumes ; we have the advantage, by making our characters moveable, to print the largest works with an inconsiderable quantity of letter ; those that served for the first sheets, serving over again for the succeeding ones : the Chinese, on the contrary, by reason of the prodigious number of their letters, are precluded this resource ; and find it more easy and less expensive to cut all their letters on wooden blocks ; and thus to make as many blocks as there are pages in a book ; and these of no farther use but for that single work. Their method of printing see hereafter.

PRINTING, *Origin of*.—Who the first inventors of the European printing were, in what city, and what year, it was at first set on foot, is a famous problem long disputed among the learned. In effect, as the Grecian cities contended for the birth of Homer, so do the German cities for that of printing.

Mentz, Haerlem, and Strasburgh, are the warmest on this point of honour : Italy also would have entered the

lifts; but the suffrages being at first divided between the first three pretenders, they are left in possession of the question, which, in reality, is not yet justly decided; though it must be owned, Mentz has always had the majority of voices.

We shall not here enter into a nice disquisition of the merits of the cause, but only propose the pretensions of each. John Mentel of Straßburgh, John Guttenberg and John Fault of Mentz, and L. John Coster of Haerlem, are the persons to whom this honour is severally ascribed by their respective countrymen; and they have all their advocates among the learned. Mentel, a physician of Paris, enters the lists in behalf of his namesake of Straßburgh; and contends that it was he who first invented printing in the year 1440, and that, in consideration of it, the emperor Frederic III. gave him a coat of arms corresponding to it, in the year 1466. He adds, that Guttenberg, whom he had taken in as a partner, or associate, carried it to Mentz, where he took in Fault a partner. John Gensfleisch, a native of Mentz, who was his servant, communicated the art to J. Guttenberg, whom Mentel had employed in making some of his tools; and becoming thus possessed of the art, they removed and settled at Mentz, where it was perfected by the assistance of John Fault. But this account depends on a Straßburgh chronicle of very doubtful authority, and is contradicted by the chronicle of Cologne, Trithemius, and Wimpeling. The last-mentioned writer expressly says, that the art of printing was invented, incompletely, at Straßburgh, by Guttenberg, and perfected at Mentz. Here Mentel acquired it from Guttenberg and Fault, and returning to Straßburgh about the year 1455, practised it in connection with Eggelstein.

The Haerlemers, with Boxhornius, Scriverius, &c. refer the first invention to Laurens Janz's Coster, or Laurence John Coster, (called Coster on account of the public office distinguished by this appellation, which he sustained at Haerlem, and which was hereditary in his family,) of Haerlem, in the year 1430, adding, that his associate Guttenberg stole away his tools while he was at church, and carried them to Mentz, where he set up for the first inventor; though others attribute this theft, &c. to his partner Fault. And others, again, with greater probability, ascribe it to John Gensfleisch senior, one of his servants, in the year 1441: and with these types, &c. of Laurence, two small works were printed at Mentz in 1442. The principal evidence in favour of Haerlem, is Cornelius, who had been a servant of Laurence, and afterwards a book-binder in that city, on whose authority Adrian Junius, M. D. founds his account, which appears to have been drawn up between the years 1562 and 1575, and published at Leyden in 1588. The learned Meerman, in his "*Origines Typographicæ*," 1765, has amply vindicated and confirmed the account which Junius gives of the fact; though he disputes and sufficiently invalidates what this writer says, as to the types which were used by Coster, at Haerlem. These, he shews, were neither cut nor fusible metal types, but separate wooden types.

Munster, Polydore Virgil, Pasquier, &c. will have Guttenburg, or Guttemburg, to have really been the inventor of printing: and add, that he took in Fault and Schoeffer for associates.

Naude, in his "*Mascurat*," espouses the cause of Fault, or Fault, or Faustus; and will have him to be the first printer in Europe, and that he took in Guttenberg for a partner. His reason for putting Fault in possession of this privilege is, that the first books that were printed appear to have

been all of his impression. To this purpose it is alleged, that it is more than probable, if Guttenberg or Coster had had a greater or an equal share in the invention, they would not have allowed him to attribute the whole to himself and his son-in-law Schoeffer, as he has done, without ever offering to do the like, or in the least contradicting him, and asserting their own right.

The true state of the case seems to be this, that metal types were first invented at Mentz; of these there were two sorts, *viz.* those that were cut, and those that were cast in matrices. The invention of the former has been ascribed by some writers to Fault, but without sufficient authority; the real inventor being John Gensfleisch senior, who had brought the art of printing with wooden types from Haerlem to Mentz, with whom John Gensfleisch junior, called Guttenberg, might probably have concurred. The era of this invention must be about the year 1442 or 1443; for John Gensfleisch senior came to Mentz in 1441, and the Latin bible, with metal types, was printed in 1450, which could not require less than seven or eight years.

The latter were invented by Peter Schoeffer, the servant and son-in-law of Fault, who settled at Mentz in the year 1449 or 1450, and having acquired under the two Gensfleischs the art of cutting types, remedied the inconvenience of this method by contriving to cast them, which must have been practised before the year 1459. The partnership that subsisted between Gensfleisch and Fault, and the relation between Schoeffer and Fault, have probably given occasion for ascribing to him the merit of the invention of printing with metal types, in which, from the connections of this kind, he probably might have had some concern.

The editions above referred to in Naude's account are, 1. The "*Codex Psalterium*," printed in 1457, which is the most ancient book known to be printed with a date or inscription, and is lodged in the emperor's library at Vienna. 2. The "*Rationale Divinorum Officiorum*" of William Durand, printed at Mentz in 1459, in folio. This "*Rationale*" is in the earl of Pembroke's library. Malinkrot has erroneously supposed this to be the first printed book. 3. The "*Catholicon Januensis*," dated in 1460, and now in the king's library. Fault's name, indeed, is not to this; but it is perfectly like the following ones where it is. It is said that the first printers did not subjoin their names and inscriptions at the end of their books till the year 1457: and this they continued to do till Fault either died or left off business. 4. The Latin Bible of 1462, being the second edition of it, now in the French king's library. 5. "Tully's Offices," in quarto (the rest being all folios), in the year 1465, and 1466, for there are copies in the Bodleian, and the library of Corpus Christi college, Oxon, of both these dates. Some eminent writers have asserted that this is the first printed book. 6. Other bibles of 1471. 7. "St. Augustine Civitate Dei," 1473. 8. "Mercurius Trimegistus de Potestate & Sapientia Dei," in 1503. 9. "Titus Livius," in 1518, &c.

Add to this, that at the end of Livy is a privilege granted by the emperor Maximilian to Schoeffer, grandson of Fault, for the sole power of printing that author for ten years; and for six years, to all the other books he should print thereafter; in consideration of Fault's having invented the art of printing. This privilege is dated 1518, and signed Jac. Spiegel.

Erasmus, however, in the epistle after that privilege, does not positively aver the fact; he only observes, that the first, or the chief inventor of that art, is held to be J.

Fault. In the advertisement to the said book, Nic. Carbachius speaks to the same effect as to the privilege, and Erasmus.

As to Guttenberg, Mentel, and Caſtor, Naude obſerves, the perſon is not yet born that can ſay he has ever ſeen books printed by any of them, before or as early as thoſe of Fault. All that is urged on their behalf, is only founded on reports, conjectures, probabilities, forged authorities, and the jealousies of cities againſt one another.

Yet Salmuth, in his additions to Pancirollus, cites a public act, by which it appears that Fault, after having invented printing, and ſuſtained it a long time on his own footing; at length took in Guttenburg as partner, to contribute to the expence; which was very great, by reaſon the firſt books were moſt of them printed on vellum, or at leaſt on parchment, and after the Chineſe way.

But the cauſe is not thus decided: the advocates for Coſter urge divers things, which ſeem to put him in the place here aſſigned to Fault. Mr. Ellis, in the Philoſophical Tranſactions, fathers books on him prior to any of thoſe above referred to Fault, and even ſome as early as 1430 and 1432. It is certain, the Haerlemers ſhew printed books of that date, which agreeing ſo well with the account given by Theod. Scriverius, and others, leaves Mr. Ellis little room to doubt, whether the honour of the invention be his or the other's due. All that belongs to Fault, according to this writer, is the honour of eſtabliſhing the art in greater luſtre and perfection at another place many years after.

But the difficulty lies, either in ſhewing why the practice ſhould be at a ſtand from 1432, to the reviving of it at Mentz by Fault and Schoeffer in 1465, or elſe in giving ſome account of the condition and progreſs of this invention during that interval.

Now, Boxhornius, Scriverius, and other authors, expreſſly affirm, that ſo large a work as the "*De Spiegel, Speculum Salutis*" of Coſter, ſhewn at Haerlem for the firſt printed book, could never be his firſt eſſay: he muſt have had the art in its rougher rudiments before, and have made many trials on leſs works: no doubt his firſt attempts were on looſe ſheets, which we may ſuppoſe were eaſily loſt. In effect, it muſt be allowed no inconfiderable argument in Coſter's behalf, that the rudeſt and moſt artleſs performances ſeem to be his. Mr. Ellis mentions ſome things of this kind without date, which he had ſeen in the king's library at St. James's, in that of Bennet college and the Bodleian at Oxford, with all the marks of the utmoſt ſimplicity, and which might fairly bid for firſt eſſays. There is ſomething ſo awkward and coarſe in them, that any body almoſt might have done them; mere nature being ſufficient, without any art or experience at all. The ink was only common writing ink, unartfully ſpread upon wooden blocks, very clumſily cut, &c.

By this time we have traced up the art to ſuch a ſtate, that it may, perhaps, ſcarcely ſeem worth the conteſting who it was invented it; and no doubt printing, as it now ſtands, owes more to the genius and addreſs of ſome of the later improvers than it did to its firſt author.

The ſame conſideration may make us more eaſy under our preſent ignorance of the inventors of moſt other arts; many of which had ſuch ſimple unmeaning originals, that it might perhaps be no mighty credit to be eſteemed the authors of inventions not leſs artful and ingenious.

We ſhall conclude this account of the origin of printing with an abridgment of the hiſtory of it, given by the late Mr. Bowyer. This writer obſerves, that the honour of having given riſe to this art has been claimed by the cities

of Haerlem, Mentz, and Straſburgh. To each of theſe cities it may be aſcribed in a qualified ſenſe, as they made improvements upon one another. But the real inventor of printing was Laurentius, of Haerlem; who proceeded, however, no farther than to ſeparate wooden types. His firſt eſſay was about the year 1430; and he died about 1440, after having printed the "*Horarium*," the "*Speculum Belgicum*," and two different editions of Donatus. Some of Laurentius's types were ſtolen from him by one of his ſervants, John Gensſeich, ſenior, who became the firſt printer in Mentz, and published, in 1442, "*Alexandri Galii Doctrinale*," and "*Petri-Hispani Tractatus*." Theſe works were executed with wooden types, cut after the model of thoſe which he had ſtolen. In 1443, Gensſeich ſenior entered into partnership with Fault (who ſupplied money), Meidenbachius, and others; and in 1444 they were joined by John Gensſeich junior, who was diſtinguiſhed by the name of Guttenberg. Guttenberg, by the aſſiſtance of his brother, Gensſeich the elder, firſt invented cut metal types, with which was printed the earlieſt edition of the bible. This edition appeared in 1450, and the completing of it took up ſeven or eight years. Guttenberg uſed none but either wooden or cut metal types. The carrying of the art to perfection was owing to Peter Schoeffer, the ſervant and ſon-in-law of Fault, who invented the mode of caſting the types in matrices; and who was probably the firſt engraver on copper-plates. The firſt book printed with the improved types was "*Durandi Rationalis*," in 1459. More copies of the earlieſt books were printed on vellum than paper. This method, however, was ſoon changed; and paper was introduced for the greateſt part of the impreſſions, a few only being printed on vellum, for curioſities, and for the purpoſe of being illuminated.

With regard to the claim of Straſburgh, it appears that Guttenberg had endeavoured to introduce printing into that city before he joined his brother at Mentz; but without ſucceſs. The firſt actual printers at Straſburgh were Mentelius and Egleſtenius; and there is no certain proof of a ſingle book having been printed there till after 1462. The diſperſion of the Mentz printers, in that year, occaſioned the art to ſpread rapidly through Europe; and in 1490 it reached even to Conſtantinople. Thoſe who wiſh to ſee this ſubject farther diſcuſſed, and to find the authorities on which this abſtract of the riſe of printing is founded, may conſult Meerman's "*Origines Typographicæ*," quarto, 1765, and Bowyer's "*Origin of Printing*," edit. 2.

PRINTING, Progreſs of. The firſt printers, then, whoever they were, made their firſt eſſays on wooden blocks, or forms, after the Chineſe manner.

It is not improbable, ſays Mr. Bagford, they might take the hint from ancient medals and ſeals. To this purpoſe, it is obſerved, that the arts and ſciences, eſpecially ſtatuary and ſculpture, were arrived at ſo great perfection among the Romans, at the time when that empire was in its greateſt glory, that it is much to be wondered at that the art of printing was not found out among them; an art ſo nearly allied to that of the cutting of ſeals and the dies of medals.

The making of theſe dies, and the ſtamping of their coins with them, was, in reality, no other than printing on metal; and their impreſſing their ſeals, cut in cornelians, agates, &c. on wax, was another ſpecies of printing on this ſubſtance. And finally, a third ſort of printing among them, was the impreſſing the name of the workmen on their pieces of fine earthen-ware.

Montfaucon, in his *Antiquities*, gives the figures and de-

scriptions of several very large sigilla of the Romans, in which the names were all cut in hollow, in capital letters; and he imagines, that the use of these was to mark large earthen vessels with, while the clay was soft, and particularly those large vessels in which the Romans kept their wines. It does not seem that this diligent enquirer into antiquity ever met with any of these sigilla with the letters or characters in relief, or standing out in the manner of our modern types for printing, since he mentions none such; yet the remains of the Roman antiquities in terra cotta, or earthen-ware, shew that they had some such, though they were less common than the others; these vessels sometimes being marked with letters going in, though in general they have them all standing out, as must be the case when the impression was given from a sigillum cut in creux.

There is now, in the collection of the duke of Richmond, a sigillum of the other more rare kind, which brings the discovery very near to that of printing: on this all the letters are raised, as is also the verge or rim of the seal in the manner of our types used this day in printing. The stamp is made of true ancient brass, and has on it the common green coat of ærugo, which distinguishes the true antique medals. The plate is nearly two inches long, and nearly an inch in breadth, and has on the back part a ring for the convenience of holding it for making the impression. The letters stand in two rows; they are the common Roman capitals, very well made, and their faces all stand exactly on the level with one another, and with the surface of the verge of the seal. This seal was exactly of the nature of our method of printing so many letters at once. It contains the name of one Caius Julius Cæcilius Hermias, some private man, as we have no account of any person of this name upon record. It served him probably to set his name to any thing, to save him the trouble of writing; and the name being that of some private man seems also to prove, that these sigilla were very common among that people. It was evidently made to be used on parchment, or some other such thin substance; and the manner of using it must have been by first dipping into ink, or some other coloured matter, not plunging it so far as to touch the ground, so that the letters only became marked, and gave their figures on the paper. The ground of this seal is very rough and uneven, and thence also it is plain, that the use of it was not to press down any soft substance, such as clay, or the like; because the imperfection of the ground would, in that case, have been seen; whereas in the use it was really intended for, the ground never gave any impression, and therefore there was no reason for bestowing any pains on the working it even.

The first use of printing among the later ages, was by wooden blocks in this very manner; and it was not till long after this invention, that we learned the way of using separate types for the letters; and these were then called *typi mobiles*, in opposition to the blocks, where the whole page was contained together, which was called *typi fixi*. This signet of the duke of Richmond's, which was found near Rome, is truly and properly one of those *typi fixi*, and prints off its impression on paper with our modern printer's ink, as well as any set of letters cut in this manner can be expected to perform. This seems, therefore, the most ancient sample of printing that we know of; for, by the appearance of the metal, it seems to be of the Higher Empire.

It is plain, by this stamp, that the very essence of printing was known to the Romans; for they had nothing to do, but to have made a stamp, with lines three or four times as long, and containing twenty lines instead of two, to have formed a frame of types that would have printed a whole

page as Coster's wooden blocks, used in printing the book called "*Speculum Salutis*," which, as some say, is the first book printed in the year 1440, and consisting of pictures of stories out of the bible, with some of the verses underneath each page; being printed from a block of wood, like a wooden cut. This was the first essay of fixed types, from which the moveable, or common separate types were soon deduced; and it seems strange that the Romans, who were as sagacious a people as any in the world, should not as easily have fallen upon the use of separate types, in which the whole art of modern printing consists, from such signets as these, as the later ages from Coster's wooden blocks, which were plainly no other than larger works of the same kind.

Cicero, in his book "*De Natura Deorum*," has a passage from which Toland supposes that the moderns took the hint of printing. That author orders the types to be made of metal, and calls them *formæ literarum*, the very words used by the first printers to express them. It is plain from Virgil, that brands, with letters of the owner's name, were in use in his time for the marking of cattle. And we have an account of the same artifice that is now used for the painting of cards being used by the emperor Justin, who could not write. There was a smooth board, with holes cut through it, in form of the letters of his name; and when he had occasion to sign any thing, this was laid on the paper, and he marked the letters with a pen or stylus dipped in red ink and directed through the holes. *Philos. Transf.* N^o 479, p. 393.

But others rather imagine the art of printing to have come from the method of making playing cards, which, it is certain, bear a nearer resemblance to the primitive process of printing than seals; as appears from the first specimens of that art above mentioned.

The book at Haerlem, the vocabulary called "*Catholicon*," and the pieces in the Bodleian and Bennet college, are all performed in this way; and the impression appears to have been given on one side of the leaves; after which the two blank sides were pasted together.

But they soon found the inconveniencies of this method, and therefore bethought themselves of an improvement; which was by making single moveable letters, distinct from one another.

These being first done in wood, gave room for a second improvement; which was the making of them, at length, of metal; and in order to that, cutting moulds, matrices, &c. for casting them.

From this ingenious contrivance we ought to date the origin of the present art of printing, as practised throughout Europe; contradistinguished from the methods of the Chinese abroad, and the card-makers at home, which were the same art, only practised in a different place, or with a different view.

And of this, Schoeffer, or Scheffer, first servant, and afterwards partner, and son-in-law of Faust, at Mentz, above mentioned, is pretty generally allowed the inventor; so that he was properly the first printer with fusile types.

But the art being yet in its infancy, there were some imperfections in the books they printed; among the rest was the want of capital letters: hence they left the places of the initial letters blank, and gave them to the illuminers to paint in gold, or azure, though others say, this was done designedly, to enable them to pass off their books for manuscripts.

Some authors tell us, that Faust carrying a parcel of his bibles to Paris, and offering them to sale as MSS., the French, upon considering the number of books, and their exact conformity with one another, even to a point, and that

the best book-writers could not be near so exact, concluded there was witchcraft in the case; and, by either actually indicting him as a conjuror, or threatening to do so, extorted the secret. And thence the origin of the popular story of Dr. Faustus.

From Mentz, about the year 1462, when it was taken, plundered, and deprived of all its former rights and franchises, the art of printing soon spread itself throughout a good part of Europe; Haerlem and Strasburgh had it very early; which, as authors represent it, occasioned their pretending to the honour of the invention.

From Haerlem it passed to Rome in 1466, where the Roman type was introduced in 1467, which was soon after brought to great perfection; and into England in the reign of Henry VI. by means of Thomas Bouchier, archbishop of Canterbury, who sent R. Tournour, master of the robes, and W. Caxton, merchant, to Haerlem, to learn the art. These privately prevailing with Corfellis, an under-workman, to come over, a press was set up at Oxford.

This account depends on the authority of an old manuscript chronicle, said to be preserved in the archbishop's palace, and cited by Atkins, in his "Original and Growth of Printing in England," published at London in 1664. This chronicle informs us, that the execution of the business intrusted with Tournour and Caxton, cost fifteen hundred marks; and that printing was set up at Oxford before there was any printing press or printer in France, Spain, Italy, or Germany, except the city of Mentz, which claims seniority as to printing even of Haerlem itself, calling herself *Urbem Moguntinam artis typographice inventricem primam*; though it is known to be otherwise, that city (as the chronicle adds) gaining that art by the brother of one of the workmen at Haerlem, who had learned it at home of his brother, and afterwards set up for himself at Mentz. This press at Oxford was at least ten years before there was any printing in Europe (except at Haerlem and Mentz), where also it was but new-born. This press at Oxford was afterwards found inconvenient to be the sole printing place in England, as being too far from London and the sea; upon which the king set up a press at St. Alban's, and another at the abbey of Westminster. But the authority of this chronicle has been warmly disputed by Mr. Palmer in his "History of Printing," 1733, book iii.; Dr. Ducarel, in his letter to Meerman, Dr. Middleton, Ames, and others, who maintain that there was no printing in this kingdom till the introduction of it by Caxton, who had acquired it in his travels abroad, about the year 1474, or as some say, 1470 or 1471.

But Mr. Bowyer, in his notes to the Abridgment of Dr. Middleton's "Dissertation on the Origin of Printing in England," hath offered several reasons to shew, that the account given in Atkins's record is not so incredible or improbable as some persons have imagined.

Mr. Meerman, in his learned work already cited, is a strenuous advocate for the authenticity of this record: and he apprehends that the period to which this history relates, must have been between the years 1454 and 1459; because Bouchier was made archbishop of Canterbury in 1454, and Edward IV. succeeded Henry VI. in 1460. This accurate writer has produced a variety of evidence in support of the claims of Corfellis, for which we must refer to his elaborate work, and particularly to his letter in reply to Ducarel, tom. ii. p. 19, &c., and to Mr. Bowyer, ubi supra; which evidence derives much confirmation from a book with a date of its impression from Oxford, anno 1468, copies of which are in several public libraries, particularly at Cambridge, Oxford, lord Pembroke's library, &c. This is a small volume of forty-one leaves in quarto, with this title; "Expo-

sitio Sancti Jeronimi in Symbolum Apostolorum ad Papam Laurentium," and at the end are the following words, "Explicit Expositio, &c. impressa Oxoniæ & finita, Anno Domini MCCCCLXVIII. XVII die Decembris."

If the authority of this book be admitted, it is a clear proof and monument of the exercise of printing in Oxford several years before Caxton began to deal in it. Dr. Middleton, indeed, endeavours to shew that the date is a false one; and, not to mention the rest of his arguments, confirms his opinion from this circumstance, that we have no other fruit or production from the press at Oxford for eleven years next following. But this objection is invalidated by two considerations; first, that Corfellis's books may have been lost, a thing by no means uncommon in those days of ignorance; and, secondly, that the civil wars broke out in 1469, which might probably oblige our Oxford printer to shut up his press.

Mr. Bowyer produces a passage from the second part of Shakspeare's Henry VI., as a farther evidence of a more early introduction of printing into England than hath generally been supposed. See also Meerman ubi supra, monitum novissimum, prefixed to tom. ii.

The result of the whole is, that this fact doth not at all derogate from the honour of Caxton, who was the first person in England that practised the art of printing with fusile types, and consequently the first who brought it to perfection: whereas Corfellis printed with separate cut types in wood, being the only method which he had learnt at Haerlem.

In 1467, printing was set up in the city of Tours; at Reuthingen and Venice in 1469; and probably in the same or next year at Paris, where Gering, Crantz, and Friburger, all Germans, invited thither by two doctors of the Sorbonne, set up a press in that learned house.

Hitherto there had been nothing printed but in Latin, and the vulgar tongues; and this first in Roman characters, then in the Gothic, and at last in Italic. But in 1480, or, as some say, in 1476, the Italians cast a set of Greek types; and it was at Venice, or, as some say, at Milan or Florence, that the first editions in that language appeared.

Here we may observe, that the first Greek printing was a few sentences of Tully's Offices at Mentz, in 1465, which were very incorrect. In the same year, some Greek quotations in an edition of Lactantius's Institutes, were neatly printed, in a monastery, in the kingdom of Naples. The first whole Greek book was the Grammar of Constantine Lascaris, at Milan, in 1476. See Bowyer, ubi supra, Appendix, N^o 1; or the excellent edition of the Biographia Britannica, by Dr. Kippis, art. Atkins, note (A).

The Italians, too, have the honour of the first Hebrew editions, which were printed about the same time with the Greek, at Soncino, a little city in the duchy of Milan; under the direction of two Jewish rabbins, Joshua and Moses, whose works are dated in the year of the world 5244, answering to the year 1484 of the Christian era.

Towards the end of the sixteenth century, there appeared various editions of books in Syriac, Arabic, Persian, Armenian, Coptic, or Egyptian characters; some to gratify the curiosity of the learned, and others for the liturgic uses of the Christians in the Levant: these were printed chiefly at Paris; whither punchcons and matrices were sent from Constantinople by M. Savary, then ambassador at the Porte.

Out of Europe, the art of printing has been carried into the three other quarters of the world: for Asia, we see impressions of books at Goa, and in the Philippines; at

Lima, Boston, Philadelphia, Mexico, &c. for America; and at Morocco for Africa.

The Turks, indeed, are said rigorously to prohibit printing throughout their empire, as imagining that the too free communication with books might occasion some change in religion or government, but this is to be understood with some limitation: and it is certain that the Jews have several editions of their books printed at Constantinople, Thessalonica, &c.

PRINTING, Method of. For the printing letters see the annexed specimen.

For the method of forming and casting them, see *Letter Foundry*.

And for the art of engraving the punches, matrices, &c. in order thereto, under the articles **ENGRAVING, PUNCHES, MATRICES, &c.**

The workmen employed in the art of printing are of two kinds; *compositors*, who range and dispose the letters into words, lines, passages, &c. according to the copy delivered them by the author; and *pressmen*, who apply ink upon the same, and take off the impression. See **COMPOSITION, &c.**

Office of the Compositor.—The types, being cast, &c. are distributed, each kind by itself, among the divisions of two long wooden frames, an upper and under one, called *cases*; each of which is divided into little cells, or boxes, of different sizes.

The boxes of the upper cases are in number ninety-eight; and in these are disposed the capitals, small capitals, accented letters, &c. In the cells of the lower case, which are fifty-four, are disposed the common running letters, with the points, commas, spaces, quadrats, &c.

Each case is placed a little aslope, like a reading-desk, that the operator may reach the upper boxes the better, and be in less danger of mixing the letters by stretching his arm over them.

The compositor's post is against the middle of the case, and he works standing, holding an instrument, usually made of iron, called the *composing-stick*, in one hand; with the other he takes the types as he requires them, out of the boxes; ranges them on a slip of brass, called a *rule*, in his composing-stick; and, putting a space, to make a blank between each two words, forms one line after another, till the stick being full, he empties it out upon another instrument, called the *galley*; several of which ranged and wedged tight in an iron frame, called a *chase*, are ready for the press.

This short view of composing may need to be farther illustrated and enlarged upon. The composing-stick, then, (represented *Plate IV. Printing, fig. 5.*) consists of a plate, or slip of iron, brass, wood, &c. more or less broad, and contrived so as to be made more or less long, according to the width of the page, and the number of lines to be composed in it.

From the right side of this plate arises a ledge *a a*, about half an inch high, running the whole length of the plate, and serving to sustain the letters, the sides of which are to rest against it; from the same plate likewise arise three other lesser pieces, *b* and *c*, *t*, two of which, *c*, *t*, are contrived to slide along it, so that the two pieces may be either approached or withdrawn at pleasure, to adjust the length of the line to the measure intended. Add, that where marginal notes, references, &c. are required in a work, the two sliding-pieces, *c*, *t*, are opened in the composing-stick to a proper distance from each other.

Before the workman proceeds to compose, a rule, or thin slip of brass plate, cut to the length of the line, and of the same height as the letter, is placed in the composing-

stick against the ledge of it, for the letter to bear immediately against.

Things thus prepared, the compositor having the copy lying before him, and the stick in his left hand, with the right he picks up the letters, spaces, &c. and places them against the rule; while with the thumb of the left he presses them close to the upper screw, or cheek: and thus keeps them tight and steady; while the other hand is constantly employed in setting in more letters; the whole being performed with a degree of expedition and address not easy to be imagined.

A line being thus composed, if it end with a word or syllable, and fill the measure, there needs no farther care; otherwise more spaces are to be put between the several words to justify the lines, *i. e.* to make the measure quite full, so that every line may end even; and thus he proceeds to another line.

The spaces here used are a sort of blanks, of the like dimensions as the letters, but less high; and whose faces, therefore, when set, do not appear, nor give any impression. They are of several kinds, according to the dimensions of the whites or intervals to be made by them, *viz.* quadrats, to fill up a break at the end of a paragraph, or the like; m quadrats, which are square, and of the thickness of an m, serving to make the distance after a period, or between sentence and sentence; n quadrats, of the thickness of an n, to be placed after colons, semicolons, and commas; and thick or thin spaces, to be used between the words in justifying, as above.

For marginal notes, in the spaces reserved for them between the two sliding pieces of the composing-stick, are put little quadrated pieces of metal, called *gustations*; which are justified by other smaller pieces; a slip of scaleboard being placed from the top of the page to the bottom, to keep the note and text at due distance.

The first line being thus completely justified, the compositor advances to the next; in order to which, he moves the brass rule from behind the former, and places it before it, and thus composes another line against it, after the same manner as the former: and thus he goes on till his stick be full, which he empties into the galley, after the manner following:

Taking the rule from behind the last line, he places it before it; and with his two middle fingers squeezes the lines in the stick close; his two fore-fingers at the same time being applied on the outside of the rule: thus he lifts them out of the stick, and clapping his two thumbs behind the first line, lifts them into the galley; taking care to disengage his two thumbs without breaking the lines.

The compositor having thus set the proper number of lines in the stick, *viz.* four, five, six, or more, and emptied them out into the galley, he again fills and empties, as before, till a complete page be formed; remembering at the bottom of every page to set a line of quadrats, and at the end of it the first word of the page ensuing, for a catch-word; and if it be the first page of the sheet, one of the letters for a signature.

The galley is a flat wooden tray or dish, in form of a long square; of a length and breadth proportionable to that of the page; it consists of two parts, the upper, called the *slice*, by which the pages of large volumes, when composed, are slid upon the stone; the other, called the *coffin*, which is the body of the galley, is ledged on three sides to contain the slice; the inner ledge not to exceed half an inch in height, that the composed page rising above it by one half the height of the letter, may be tied up, or bound down, and removed without danger. When at work,

the compositor places this galley at the top of the case, and it is prevented by a wooden pin from sliding down the boxes.

The page, then, being composed, and ranged in the galley, he ties it up in it with a cord or packthread, and lets it by, and proceeds to the next, till the number of pages of the sheet be completed; which done, he carries them to the imposing or correcting stone, there to range them in order in a chase; which they call *imposing*.

The chase is a rectangular iron frame of different dimensions, according to the size of the paper to be printed on, having two cross pieces of the same metal, called a *long* and *short cross*, mortised at each end into the frame, so as to be taken out occasionally.

By the different situations of these crosses, the chase is fitted for different volumes, for quartos and octavos; one traverses the middle lengthwise, the other broadwise, so as to intersect in the centre, which is the most customary situation; for twelves and twenty-fours, the short cross is shifted nearer to one end of the chase. For folios, the long cross is left entirely out, and the short one placed in the middle; and for broad-sides, or sheets printed on one side only, both crosses are set aside.

To dress the chase, or range and fix the pages in it, they make use of a set of furniture, consisting of reglets, or slips of wood of different dimensions, and about half an inch high, that they may be lower than the letters; some of these are placed at the top of the pages, called *head-sticks*; others between them to form the inner margin, called *gutter-sticks*; others at the sides, called *side-sticks*; and others at the bottom, called *foot-sticks*.

The pages then being placed in order on the stone, the chase is put over them, and the reglets applied between the letter and the chase, in the position above-mentioned; the whole is locked up by means of small pieces of wood, cut in the wedge-form, called *quoins*, which are driven with a mallet and shooting-stick to a sufficient tightness. Before the form be quite locked up, they press down the same, by passing a smooth piece of wood, called the *plainer*, over the letters, to make their surfaces stand flat and even; and, when locked up, they shake it, to see that nothing stir.

In this condition, the work is called a *form*, containing more or fewer pages, according to the volume.

As there are two forms required to every sheet, when both sides are to be printed, it is necessary they be exactly of the same length and breadth; *i. e.* the corresponding reglets, head-sticks, &c. are to be equal in both forms, that the pages may fall exactly on the back one of another; which is called *register*.

Here, then, properly ends the compositor's office; the form, thus finished, being to be committed to the pressman.

Indeed, as it is impossible but there must be mistakes in the work, either through the oversight of the compositor, or by the casual transposition of the letters in the cases; after drawing off a proof, it is delivered to the corrector; who reading it over, and rectifying it by the copy, it is remanded to the former operator, to be corrected accordingly. For the characters used in correcting a sheet for the compositor, see CORRECTION.

The compositor, then, unlocking the form upon the correcting-stone, by knocking out or loosening the quoins, and spreading his corrected proof so as that the lines of it range with the respective ones of the metal, by running his eye along both, he easily spies where corrections are to be made; according to which, he proceeds to pick out the

faulty letters, points, &c. with a sharp-pointed steel bodkin, and puts others in their places.

Where the alterations are considerable, and particularly where insertions or omissions are to be made, there usually arises a necessity of over-running; in order to which, they must decompose, or return the lines back from the chase into the galley, and from the galley again into the composing-stick, to be new-modelled and rectified accordingly.

If, *e. gr.* one or more words, to be inserted in a line, cannot be gotten in by changing the spaces of the line for lesser ones, part of the line must be put back into the close of the preceding one, or forward into the beginning of the subsequent one, or both, till room is obtained. If the insertion be large, several lines will need to be over-run, either backward or forward, till a break is arrived at; when if it be not gotten in, a line is to be driven out; and, to get in that line, the next pages, either backward or forward, must sometimes be over-run before it can come in.

When an omission is to be made, the contrary course must be taken. If it be but little, the compositor takes it out, and drives out the remaining matter, either by enlarging his spaces, or bestowing the beginning of the following, or the close of the preceding line therein. If it be considerable, he may be obliged to over-run several pages before it can be driven out.

As to the faults which escape the corrector and compositor, they are usually noted in what we call the *errata*. The ancient editions had no errata; but in lieu of it, they corrected the faults in each printed copy with a pen, which was easy enough in those days, though impracticable now. In effect, we have anciently had printers, who did not need an errata of above five articles in a volume of five hundred sheets; and the distinguishing excellence of printing is correctness; and in this respect many of our modern printers deserve much commendation.

Besides the several kinds of letters and characters above-mentioned, used in printing, they have likewise rules for black lines, borders, and head and tail-pieces, accommodated to the several kinds of letters.

The rules for black lines are of brass, and are made exactly of the height of the letter; otherwise they will hinder the neighbouring letters from printing, or will themselves be hindered by them. These the compositor occasionally cuts into proper lengths, as his work requires.

The *borders*, or *flowers*, are a kind of ornaments, in form of long bars, serving for the division of books, chapters, &c. Their depth is proportioned to the letter; and their length adjusted to the page; for being composed of several moveable pieces, it is easy to lengthen or shorten them.

The *head* and *tail-pieces*, cut either in wood, pewter, brass, copper, or silver, are compartments used at the beginnings and endings of books.

The initial letters are sometimes cut in wood, and figured; sometimes cast like the other characters.

For the convenience of the binding, the printers had early recourse to signatures, *i. e.* letters of the alphabet placed at the bottom of the first page of each sheet, which shew the order they are to be bound in, as well as whether the quires are complete; which method is still continued.

The *catch-words* serve nearly the same purpose; these are the first words of each page, which are inserted at the bottom of the preceding pages. The number of the pages are equally serviceable to the reader and the binder, to guide to references, and to warrant the book duly bound and collated; some printers formerly put them at the bot-

toms of the pages; but custom has now carried it for the tops.

In the infancy of printing, they had likewise a *registrum chartarum* for the convenience of the binders: to draw this, at the end of each volume, they collected the signatures, and the first words of the first four sheets of each alphabet. To abridge it, they afterwards contented themselves to express the signatures, and how often each letter was repeated; but the *registrum* has been now long disused.

Pressman's office, or PRINTING, properly so called. To work off the form thus prepared and corrected by the compositor, there are three things required, paper, ink, and a press.

To fit the paper for use, it is to be first wetted or moistened, by dipping several sheets together in water: these are afterwards laid in a heap over each other; and to make them take the water equally, they are all pressed close down with a weight at top. As to the degree of wetting, it must be according to the quality of the paper, and the size of the letter; small letters, and stiff paper, requiring most wetting.

PRINTING Ink is of two kinds, black and red; the last occasionally used in title-pages, calendars, &c. the first for the body of books. The composition of each, though now reckoned no part of the printer's business, but usually furnished them by other hands, is as follows:

For black ink.—A hundred pounds of nut or linseed oil, being reduced, by boiling, to the consistence of a syrup, are cleansed and purified by throwing into them two pounds of coarse bread, and about a dozen onions. Nut-oil is supposed to be the best, and is accordingly preferred for the black ink, though the darker colour which it acquires from the fire makes it less fit for the red. This oil is boiled in an iron pot, capable of holding at least half as much more, because it swells very much; when it boils it is kept stirring with an iron ladle; and if it does not itself take flame, it is kindled with a piece of lighted paper, or burning wood, in order to increase its consistence and tenacity, and to diminish its greasiness. The oil is suffered to burn for half an hour or more; and the flame being then extinguished by covering the vessel close, the boiling is afterwards continued, with a gentle heat, till the oil appears of a proper consistence; in which state it is called varnish; of which there should be two kinds, one more and another less boiled; or a thicker and thinner, to be used for different purposes, and in different weathers. The oil is said to lose in being boiled into thick varnish from a tenth to an eighth part of its weight; but different oils, and perhaps the same oil in different states, differ in this respect. The design of adding the bread and onions is more effectually to destroy the greasiness; but Dr. Lewis doubts, whether additions of this kind are of much use. They then boil thirty or thirty-five pounds of turpentine apart, till such time as they find, upon its cooling on paper, that it breaks clean, like glass, without pulverizing; for if it pulverize easily, it is a sign it is burnt. The oil and turpentine being thus prepared, the first is gently poured, half cold, into the latter; and the two stirred together with a stick till they be well mixed: after which the boiling is repeated and the composition is set by, to be used occasionally. The turpentine is used in order to give a greater body to the varnish, and to increase its drying quality; and with some artists, litharge has in this intention been a secret. M. le Breton, in the *Encyclopédie*, observes, that when very old oil is used, neither turpentine nor litharge are needful; but that when the oil is new, some turpentine ought to be

employed, because without it, the smearing of the paper, by the spreading or coming off of the ink, cannot be avoided; and he adds, that it is much more eligible to use old oil than to have recourse to this correction of the new: both turpentine and litharge, particularly the last, making the mixture adhere so firmly to the types, that it is scarcely to be got entirely off by the ley, whence the eye of the letter is soon clogged up.

Now to proceed to make ink, they take a quantity of this mixture, and add to it a certain quantity of lamp-black, working it up with a kind of wooden mallet, or braver, till the whole be incorporated, and reduced into a kind of pulp; which is the ink for use.

Where, note, that its thickness or strength is always to be proportioned to that of the paper, and the warmth of the weather; strong paper, and hot weather, requiring strong ink: and that the strength or weakness of the ink depends on the greater or the less degree of coction of the varnish. According to M. le Breton, two ounces and a half of the lamp-black are sufficient for sixteen ounces of the varnish. *Lewis's Commerce of Arts*, p. 371.

For red ink, they use the same materials as for black, excepting only, that instead of lamp-black, they add a proper quantity of vermilion. Some hold, that by mixing and incorporating the bigness of a nut of fish-glue, or brandy, or the white of an egg, with the ink, the vermilion acquires a greater lustre.

The PRINTING Press is a well contrived machine, and at a very early period of the art was brought to a degree of perfection, which has not admitted of any very material improvements till the present age. Who first invented it we are not informed, but from Mr. Moxon we learn, that it was very greatly improved by William Janfen Blaew, who established a printing-house at Amsterdam, where he printed many books and maps, which he made from the observations of the famous Tycho Brahe, who had for many years employed him as an assistant, and to make his instruments.

Fig. 1. Plate IV. Printing, is a representation of the printing press in perspective. It has two principal parts, each of which is composed of several others: the first is the body of the press, which is a frame containing the screw, and platen, or surface which produces the pressure upon the paper; and the other is the carriage, on which the *form* of types is laid, and has the means of being drawn out of the body of the press, to remove the paper when printed, and to substitute another sheet. For the convenience of changing the paper, the carriage is provided with frames, called the tympan and frisket, which fold upon each other and enclose the sheet between them, and are then again folded down upon the types.

The body of the press consists of two strong posts, *b, b*, placed perpendicular, called the cheeks, which are joined together by four horizontal cross pieces; the upper of these, *a*, is called the cap, and has no office but to retain the two cheeks at their required distances asunder: the next cross piece, *b*, is called the head; it is fitted by tenons at the ends into mortises between the cheeks, and these mortises are filled up with pieces of pasteboard or soft wood, in such a manner as to admit of a small motion or yielding. The head is sustained by two long screw-bolts, which suspend it from the cap: in the head is fixed a brass nut, containing a female screw or worm, which is fastened in the wood by two short bolts to keep it up: the worm is adapted to receive the screw by which the pressure is produced. The third cross piece, *c c*, called the shelves, or till, is to guide and keep steady a part, *i*, called the hose, in which the spindle of the screw (to be spoken of hereafter) is inclosed. The fourth cross plank, *f f*, called the winter, is fitted between the cheeks to bear the carriage;

it sustains the effort of the *pres*s beneath, as the head does above, each giving way a little, the one upwards the other downwards, to make the pull the easier. The spindle, *g, g*, is an upright piece of iron, pointed at the lower end with steel, having a male screw formed on its upper end, which enters about four inches into the female screw or worm fixed in the head: through the eye of this spindle is fixed the bar or handle, *b*, by which the pressman works the *pres*s. The platen *k*, or surface which acts upon the paper to produce the impression, is suspended from the point of the spindle by means of a square block or frame of wood, *i*, called the *hose*, which is guided by passing through the shelves *e, e*: the lower part of the spindle passes through the *hose*, and its point rests upon the platen *k*, being received into the plug fixed in a brass pan supplied with oil, which pan is fixed to an iron plate let into the top of the platen *k*. The pressman then, by pulling the bar *b*, fixed in the eye of the spindle *g*, by an iron key turns the spindle, and by means of its screw presses down the platen upon the *form* of types, which is covered with the paper, tympan, and its blankets, all these parts being brought under the platen by the carriage, when the impression is to be given. That the platen may be suspended from the spindle, and rise up again with it, the *hose*, *i*, is attached to the spindle by the *garter*; this is a fillet of iron screwed to the *hose*, and entering into a nick or groove formed round the upper part of the spindle; it prevents the *hose* falling down on the spindle. At each corner of the lower part of the *hose* there is an iron hook fastened, and from these to similar hooks, fastened at each corner of the platen *k*, cords or packthread are looped to suspend the platen, and they are exactly adjusted, to hang the platen truly level.

The carriage *l*, which is the other principal part of the *pres*s, is adapted to run into the space between the cheeks under the platen. It is supported upon the ribs *n*, which are part of a horizontal wooden frame, having its fore-part supported by a wooden prop *m*, called the fore-stay, while the other end rests on the *winter*. On the rails of this frame two long iron bars or ribs are nailed, and under the plank of the carriage are nailed short pieces of iron or steel, called *cramp irons*, which slide upon the ribs, when the carriage is run in or out, by the following means. Beneath the carriage is placed a small spindle called the *spit*, with a double wheel formed in the middle of it, round which leather girts are passed and fastened, the opposite ends being nailed to each end of the plank, *l*, of the carriage. On the extreme end of the *spit* is fixed the handle or rounce *p*, by which the pressman turns the *spit*, and this, by means of the wheel and straps, runs the carriage in or out at pleasure. The carriage itself consists of a strong wooden plank *l*, upon which a square frame of wood is fixed, to form the coffin or cell, in which a marble or polished stone is inclosed, for the *form* of the types to be laid upon. To this coffin are fastened leather stay-girts, one to each side, which being at the opposite ends fastened to the cheeks of the *pres*s, prevent the carriage running too far out, when drawn from under the platen. On the fore-part of the plank is a gallows *r, r*, which serves to sustain the tympan, when turned up from off the *form*, on their hinges. The tympan, *s, s*, are square frames covered with parchment. The frames are made of three slips of very thin wood, and at the top a slip of iron, still thinner, called a head-band. The two tympan are fitted together by the frame of one, being small enough to lie within the other: the outward tympan is fastened with iron hinges to the coffin. Between the two parchments of the tympan two or three thicknesses of blankets are placed, which serve to make the impression of the platen upon the surface of

the letters more equal, as also to prevent the letters from being broken by the force of the *pres*s. The use of the inner tympan is to confine these blankets. The *frisket*, *t*, is a square frame of iron, made very thin, also covered with paper or parchment, and fastened to the head-band of the outer tympan by hinges: it folds down upon the tympan, to enclose the sheet of paper between them, the parchment or paper with which the *frisket* is covered being cut out in the necessary places, that the sheet, when placed between the tympan and *frisket*, and both together folded down on the *form*, may receive the ink from the types in the pages; but the *frisket* sheet keeps the margins clean. The tympan and *frisket*, when folded down, lie flat upon the *form*, and the carriage with them is run into the *pres*s; but when the sheet is to be taken out, the tympan is lifted up upon its hinges, and rests, as represented, in an inclined position against the gallows *r*, before mentioned, at the back part of the carriage; then the *frisket*, *t*, is lifted up on its hinges, and sustained by a slip of wood, *w*, hanging from the ceiling, whilst it continues open, to take out the printed sheets and put in others.

To regulate the margin, and make the lines and pages answer each other when printed on the opposite side of the sheet, two iron points are fixed to the middle of the wooden sides of the frame of the tympan, which make two holes in the sheet. These holes are placed on the same pins, when the sheet is returned for making an impression on the other side, which is called the *reiteration*, and the pins are adjustable, that they may make the impressions of the opposite sides exactly correspond.

The ink is applied upon the *form* by balls, which are a kind of wooden cups with handles, the cavities of which are filled with wool, or hair, covered with sheep's skin nailed to the wood. One of these the pressman takes in each hand, and applying them on the ink-block, to charge them with ink, he works them one against the other, to mix and distribute the ink equally; and, at last, smears over the *form*, by beating or dabbing them several times over the whole face of it; this leaves the *form* in a condition to be passed under the *pres*s, with the moistened paper laid on it.

To prepare the *pres*s for working, the parchment of the outer tympan, against which the sheet is to be laid, is wetted till it is very soft, in order to render the impression more equable; the blankets are then put in, and secured from slipping by the inner tympan. Then, while one pressman is beating the letter with the balls, covered with ink, taken from the ink-block, the other person places a sheet of paper on the tympan, turns down the *frisket* upon it, to inclose it, keep the margins clean, and prevent it slipping; then folding the tympan down upon the *form*, and turning the rounce, *p*, with his left hand, he brings the *form*, with the stone and carriage, (which altogether weighs about 300 lbs. weight,) under the platen; pulls the bar with the right hand, by which means the platen presses the blankets and paper close upon the letter, whereby half the *form* is printed; then releasing the bar, he advances the *form* still forward into the *pres*s, by turning the rounce, and gives a second pull: now letting go the bar, he turns back the *form*, lifts up the tympan, and opens the *frisket*, takes out the printed sheet, and lays on a fresh one; and this is repeated, until he has taken off the impression for the full number of sheets the edition is to consist of. One side of the sheet being thus printed, the *form* for the other is laid upon the *pres*s, and worked off in the same manner; the sheet being so disposed, that the iron points shall pass through the holes already made in the sheet.

Sometimes it is required to cut the *frisket* afresh, where

the second side is to be more or less full of printing than the first, as is frequently the case at the beginning and ending of books, half pages at the ends of chapters, &c.

The number of sheets of the edition being complete, the form is to be separated: to restore the letters into the compositors' cases, they first wash it in a strong ley, to take out the remains of the ink, scouring it with a brush, and then with fair water. This done, it is carried to a wooden frame to be unlocked, and the furniture, *i. e.* the sticks and quoins, taken off, to disengage it from the chase. Then the compositor, taking out several lines at once upon a little brass ruler, replaces each letter in its proper box, to be again used in the remainder of the impression; which last operation they call *distribution*.

The operations of the printing press, when conducted by an expert pressman, are performed with a surprising rapidity; but the labour is very great. Two men take it by turns to *pull*, that is, work the press, and *beat*, or ink the types. Whilst one workman is employed in pulling the sheet, his comrade is distributing the ink on his balls, by first applying them to the ink-block, which is a small shelf fixed up against one of the cheeks of the press, and has ink spread out upon it by the slice and *brayer*, which is a wooden muller to mix and grind the ink; then applying the balls together, and turning them round in his hands, whilst the surfaces are rolled or dabbed against each other, the ink becomes equally distributed over them. By this time the pressman having made the pull, and opened the tympan, the other instantly begins the beating, whilst the pressman gets the sheet changed. In beating, he holds a ball in each hand, and applies them upon the types, with the handles in an inclined position; and then he mounts the handles perpendicular, by which means the leather is rolled over the surface of the types, and they are effectually inked; but if they were moved in any other way, the hollows would scrape off the ink, and clog up the letters. Having thus inked a space of as much extent as the two balls will conveniently cover, they are lightly lifted off the letters, and removed to another part, which is inked in the same manner, till the whole sheet is gone over.

The pressman, during the beating, has removed the printed sheet, and laid another evenly upon the tympan, which is done with great address; then folding down the frisket upon it, and shutting both together down upon the form, he runs in the carriage as before-mentioned, to take the first pull; for the platen being only half the size of the sheet, it is printed at twice, and the first time the carriage is run into the press, the pressman knows by a chalk mark previously made on the carriage when the first half of the sheet is under the platen; he now makes his pull, and letting the handle go back, runs the carriage in again, till the other half of the sheet comes under the platen, and then makes a second pull. In this operation he leans his body back, and places his foot against a foot-board beneath the press, to gain a greater purchase. Presses are, in general, adapted for the screw to make a sufficient pressure by a quarter turn of it, but this the pressman can vary to his own inclination, by packing up the head, *b*, of the press with pieces of pasteboard in the mortises, till it yields as much as he requires for a *long pull*; or if he puts blocks of wood to fill up the mortises, it will make a *short pull*, which has much the advantage of the other, in respect to the total exertion it requires; but then the handle being suddenly checked on coming to the pressure, it gives a shock to the whole body, which few men can bear. Strong men will work best with a solid press.

The severe labour of printing, by the ordinary press,

has, for a long time past, rendered it very desirable to obtain an accession of power. Many attempts have been made to produce a press which would print the whole surface of a sheet at a single pull: the first which has come to our knowledge was brought from France many years ago, and was called the Apollo press. It was a wooden press of the ordinary construction, except that the platen was composed of an iron plate instead of a wooden plank, and made sufficiently large to print the whole sheet at once: the under surface of it was covered with brass, and made truly flat. The screw, or spindle, instead of being turned by the bar or handle, in the usual manner, was united, by connecting rods, with a long lever, placed at the side of the press, and the man worked it by applying both hands to the lever, to bring it down nearly by the same action as working the lever of a pump; this action, requiring a motion of the whole body, was found intolerably fatiguing, and in consequence they were soon disused, even for printing newspapers, where expedition is a superior consideration to every other.

Among the contrivances we have met with for improved printing presses, the first which has been successful in a long course of practice, was invented many years ago by Mr. Roworth, a printer in London. Instead of the screw he uses a plain vertical spindle, furnished with a bar, hose, &c. just as usual; but the upper part, where the worm is usually cut, is a plain cylindric spindle, and fits into a socket fitted into the head of the press. Upon the upper end of the spindle, just beneath the head, a short cross arm is fixed, which acts against a circular inclined plane fixed under the head of the press; therefore, by turning the spindle, the cross arm acts against the under side of the circular inclined plane, and causes the spindle to descend in the same manner as the screw, but with this advantage, that the inclined plane is formed with a rapid descent at the time the action first begins; but when the platen has come down to the tympan, and the pressure begun, the plane has a very slight inclination, and therefore a great power to produce the impression; and this power increases as the resistance increases. Still, from the manner in which the platen is first brought down, there is not, on the whole, that corresponding loss of time which takes place in the usual mechanical combinations for producing a great power. A great advantage is also derived in the working of this press, from making the inclined plane and cross arm of hardened steel.

The Stanhope press, which is now becoming general, has this property in a higher degree, and is therefore capable of printing a double surface to the common press, with a very small portion of the power which that required.

A Stanhope press is delineated in *Plate I. Printing*, *figs. 1 and 2* being elevations, and *fig. 3* a plan. *AA* is a massive frame of cast iron, formed in one piece: this is the body of the press, in the upper part of which a nut is fixed for the reception of the screw *b*, and its point operates upon the upper end of a slider *d*, which is fitted into a dovetail groove formed between two vertical bars, *e, e*, of the frame. The slider has the platen, *DD*, firmly attached to the lower end of it; and being accurately fitted between the guides *e, e*, the platen must rise and fall parallel to itself when the screw, *b*, is turned. The weight of the platen and slider are counterbalanced by a heavy weight, *E*, behind the press, which is suspended from a lever *F*, and this acts upon the slider to lift it up, and keep it always bearing against the point of the screw. At *G* are two projecting pieces, cast all in one with the main frame, to support the carriage when the pull is made; to these the rails, *H*, are screwed, and placed truly horizontal for the carriage, *I*, to run upon them, when it is carried under the press to re-

ceive the impression, or drawn out to remove the printed sheet. The carriage is moved by the rounce or handle K, with a spit and leather girts, very similar to the wooden prefs. Upon the spit, or axle of the handle K, a wheel, L, is fixed, and round this leather belts are passed, one extending to the back of the carriage to draw it in, and two others, which pass round the wheel in an opposite direction, to draw it out. By this means, when the handle is turned one way it draws out the carriage, and by reversing the motion it is carried in. There is likewise a check strap, f, from the wheel down to the wooden base, M, of the frame, and this limits the motion of the wheel, and consequently the excursion of the carriage. The principal improvement of earl Stanhope's prefs consists in the manner of giving motion to the screw, b, of it, which is not done simply by a bar or lever attached to the screw, but by a second lever; *e. gr.* the screw, b, has a short lever, g, fixed upon the upper end of it, and this communicates by an iron bar, or link, h, to another lever, i, of rather shorter radius, which is fixed upon the upper end of a second spindle, l, and to this the bar or handle, k, is fixed. Now when the workman pulls this handle, he turns round the spindle l, and by the connection of the rod, h, the screw, b, turns with it, and causes the platen to descend and produce the pressure. But it is not simply this alone, for the power of the lever, k, is transmitted to the screw in a ratio proportioned to the effect required at the different parts of the pull; thus at first, when the pressman takes the bar, k, it lies in a direction parallel to the frame, or across the prefs, and the short lever, i, (being nearly perpendicular thereto,) is also nearly at right angles to the connecting rod h; but the lever, g, of the screw makes a considerable angle with the rod, which therefore acts upon a shorter radius to turn the screw; because the real power exerted by any action upon a lever, is not to be considered as acting with the full length of the lever between its centres, but with the distance in a perpendicular drawn from the line in which the action is applied to the centre of the lever. Therefore, when the pressman first takes the handle, k, the lever, i, acts with its full length upon a shorter length of leverage, g, on the screw, which will consequently be turned more rapidly than if the bar itself was attached to it; but on continuing the pull, the situation of the levers change, that of the screw, g, continually increasing in its acting length, because it comes nearer to a perpendicular with the connecting rod, and at the same time the lever, i, diminishes its acting length, because, by the obliquity of the lever, the rod, h, approaches the centre, and the perpendicular distance diminishes; the bar or handle also comes to a more favourable position for the man to pull, because he draws nearly at right angles to its length. All these causes combined have the best effect in producing an immense pressure, without loss of time; because, in the first instance, the lever acts with an increased motion upon the screw, and brings the platen down very quickly upon the paper, but by that time the levers have assumed such a position as to exert a more powerful action upon each other, and this action continues to increase as the bar is drawn forwards, until the lever, i, and the connecting rod are brought nearly into a straight line, and then the power is immensely great, and capable of producing any requisite pressure which the parts of the prefs will sustain without yielding. The handle is sometimes made to come to rest against a stop, which prevents it moving further, and therefore regulates the degree of pressure given upon the work: but to give the means of increasing or diminishing this pressure for different kinds of work, the stop is made moveable to a small extent.

A better plan is adopted by some makers of the Stanhope prefs, *viz.* to have a screw adjustment at the end of the connecting rod h, by which it can be shortened; it is done by fitting the centre pin which unites it to the lever, g, in a bearing piece, which slides in a groove formed in the rod, and is regulated by the screw. This shortening of the connecting rod produces a greater or less descent of the platen, when the handle is brought to the stop.

The carriage of the prefs in *Plate I.* is represented with wheels, m, m, beneath, to take off the friction of moving upon the ribs, H. These wheels are shewn at *fig. 4*, which is a section of the screw and the platen, with the carriage beneath it; and *fig. 5* is a plan answering to it. *Fig. 6* is a figure of the carriage, inverted, to shew the wheels; their axles, n, are fitted to springs, p, and these are adjustable by means of screws, r, so that the carriage will be borne up to any required height. This is so regulated, that when the carriage is run into the prefs, its lower surface shall bear lightly upon the solid cheeks, G, which are part of the body of the prefs, and these support it when the pressure is applied, the same as the winter of the old prefs: but the wheels by their springs act to bear up great part of the weight of the carriage with the types upon it, and diminish the friction, yet do not destroy the contact of the carriage upon the ribs, because this would not give the carriage that solidity of bearing which is requisite for resisting the pull. This is only at the time when the carriage is run into the prefs, because as it runs out, the ribs on which the wheels run rise higher, and therefore the wheels support the whole weight. The manner in which the wheels run in rebates or recesses in the edges of the ribs, is shewn at *fig. 2*. The carriage is made of cast iron, in the form of a box, with several cross partitions, which are all cast in one piece, and though made of thin metal, are exceedingly strong: the upper surface is made truly flat, by turning it in a lathe. The same of the platen, which is likewise a shallow box: the slider, d, has a plate formed on the lower end of it, which is fixed by four screws upon the top of the platen, and thus they are united. At the four angles of the carriage, pieces of iron, r, (*fig. 5*.) are screwed on, to form bearings for the quoins or wedges which are driven in to fasten the form of types upon it in the true position for printing. The tympan, P, (*fig. 1*.) is attached to the carriage by hinges, with an iron bracket or stop to catch it when it is thrown back: the frisket, R, is joined to the tympan, and when opened out, rests against a frame suspended from the ceiling. The register points are the same as before described in the wooden prefs, and all the operations of working are exactly the same. The iron frame, A, of the prefs is screwed down upon the wooden base, M, by bolts, which pass through feet, s, projecting from the lower part of the iron frame. Another wooden beam is fixed into the former at right angles, so as to form a cross, which lies upon the floor. The ribs, H, for the carriage to run upon are supported from the wooden base by an iron bracket, T.

The advantages of the iron presses in working are very considerable, both in saving labour and time. The first arises from the beautiful contrivance of the levers, the power of the prefs being almost incalculable at the moment of producing the impression; and this is not attended with a correspondent loss of time, as is the case in all other mechanical powers, because the power is only exerted at the moment of pressure, being before that adapted to bring down the platen as quickly as possible. This great power of the prefs admits of a saving of time, by printing the whole sheet of paper at one pull, the platen being made sufficiently large for that purpose; whereas, in the old prefs, the platen is only half

the size of the sheet. In the Stanhope press, the whole surface is printed at once, with far less power upon the handle than the old press, when printing but half the surface. This arises not only from the levers, but from the iron framing of the press, which will not admit of any yielding, as the wood always does, and indeed is intended to do, the head being often packed up with elastic substances, such as pasteboard, or even cork. In this case much power is lost, for in an elastic press the pressure is gained by screwing or straining the parts up to a certain degree of tension, and the effort to return produces the pressure: now in this case, the handle will make a considerable effort to return, which, though it is in reality giving back to the workman a portion of the power he exerted on the press, is only an additional labour, as it obliges him to bear the strain a longer time than he otherwise would. The iron has very little elasticity, and those who use them find it advantageous to diminish the thickness of the blankets in the tympan to one very thin piece of fine cloth; the lever has then very little tendency to return, and the pull is easy in the extreme, requiring very little more force to move it at the latter, than at the first part: indeed it is so different from the other press, that when an experienced pressman first tries it, he cannot feel any of that re-action which he has been accustomed to, and will not believe, till he sees the sheet, that he has produced any impression at all; and for many days after he begins to work at an iron press, he by habit throws back all the weight of his body in such a manner, as to bring the handle up to its stop with a concussion that shakes his arm very much; and in consequence most pressmen, after a few hours' work, feel inclined to give up the iron press; but when they have once got into a new habit of standing more upright, and applying only as much force as it requires, the labour of the pull becomes less than that of running the carriage in and out; and men who are accustomed to the iron presses only, would be scarcely able to go through the work of the old press.

The Stanhope presses have come very much into use, and many people are engaged in making them. The first of these are Messrs. Walker, of Oxford-street, who have the advantage of being assisted by the inventor, earl Stanhope; they have a very good machine for turning the surfaces of the platen and carriage, so as to produce very accurate planes; which is a great advantage, as it permits a much thinner blanket than could otherwise be used.

Mr. De Heine has a patent for a Stanhope press, which answers extremely well: the only material alteration is, that he has substituted a spiral, or curved inclined plane, in place of the screw, which is fixed to the head of the press; and a cross arm properly formed, and fixed on the upper end of the spindle, which stands in place of the screw, acts against the fixed inclined plane. The action is very nearly the same as the screw, except that the surfaces admit of being made of hardened steel, and thus diminish the friction very much. The inventor of this for the common press was, as we have before mentioned, Mr. Roworth, but Mr. De Heine has combined it with the levers and iron frame of the Stanhope press. This *Cyclopædia* is printed by Stanhope presses.

Mr. Peter Kier, of Camden Town, has made several Stanhope presses of a very good construction, the strength of all the parts being very well proportioned, so that his presses are not more liable to break at one part than another. The slider, *d*, he has made in a very convenient manner, by boring out a cylindrical hole down the centre of the press with a boring machine, and into this a cylinder is accurately fitted, the platen being fixed on the lower end of it. To prevent

it from turning round, a flat side is made to the cylinder, and a bar of iron is screwed across the two cheeks *e, e*, between which the hole is bored, and bears against the flat side of the cylinder. Another improvement is in the spindle *l*, to which the handle is affixed: this has a screw cut upon the lower end of it, which is fitted into a nut, and thus, when it is turned round, the spindle rises and falls a quantity equal to the descent of the screw, *b*, in the same period. By this means, the connecting rod, *b*, always draws in an horizontal direction, whereas, in the other presses, one end remains at the same level, whilst the other descends, in consequence of which the joints wear irregularly. On the whole, Mr. Kier's improvements, though they do not constitute a feature of the invention, contribute much to the accurate performance and durability of the machine.

The form he has adopted for the frame, *A A*, is very judicious; that in our plate is unnecessarily strong, having been made at an early period of the invention, when, from being unacquainted with the full power of the levers, many of the presses were broken by the strain, and some makers then determined to put in such a mass of metal, as to resist the utmost efforts of a man at the handle; but being now better understood, they are made much lighter than in the one in our plate, and sufficiently strong.

Several Stanhope presses, that is, presses having levers to work the screw, have been made in wood by Mr. Brooke, or altered from the old wooden presses; but though this is an improvement upon them, it is greatly inferior to the iron frame, which, for the reasons we have given, has a share in the saving of power.

Mr. Medhurst, of Denmark-street, Soho, has produced a printing press of great merit, from its simplicity, and it has the same advantage, in point of power, as lord Stanhope gains by the compound levers. It is a common press in all its parts, but the platen is made the full size of the sheet, and instead of a screw, a plain spindle is employed: on the lower part of it, just above the bar, a circular plate is fixed, and affords steps for the points of two iron rods, which extend up to the head, and are there supported by their points entering sockets. When the platen is up, these rods stand in an inclined position, although both the ends of them are at the same distance from the centre of the spindle; but when the spindle is turned by the bar, the circular plate, in which the lower points of the iron rods rest, turns round in a circle, and the upper ends remaining stationary, they of course come towards a vertical position, in which motion the spindle and platen are forced to descend, in the same manner as though a screw was employed; but this motion has every advantage of the Stanhope levers, or Mr. Roworth's press, without the friction of either, for the power increases as the resistance increases, and when the rods come nearly parallel to the spindle, or into a vertical position, the power is immensely great. We think a press of this kind, if made of iron, and with the other advantages of lord Stanhope's, would be much simpler, and rather better, because the friction and wear are inconsiderable, if the points of the rods and their sockets are hardened.

We have been shewn a model of a new kind of press invented by Mr. Ruthven of Edinburgh; it differs from others in the following circumstances. The form of types, instead of being situated on a running carriage, is placed upon a stationary platform or tablet, which is provided with the usual apparatus of tympan and frisket, with points, &c. to receive the sheet of paper, and convey it to its proper situation on the face of the types, after they have been inked. The machinery by which the power for the pressure is produced, is situated immediately beneath this tablet, and the

platen or surface which is opposed to the face of the types to press the sheet of paper against them, can be brought over the types, and connected at two opposite sides or ends with the machinery beneath the table. By this machinery it is so forcibly pressed or drawn down upon the paper which lays over the types, as to give the impression, which being thus made, the platen can be disengaged from the machinery, and removed from off the types by a motion of the foot, to take out the paper and introduce a fresh sheet.

The machinery for producing the pressure is a combination of levers, actuated by a crank, or short lever, turned by a winch or handle, to which the pressman applies his left hand, just as he does in the present to the rounce or handle of the spit, the handle being placed in the same situation for that purpose. The levers beneath the table are well contrived to have the best effect in saving time, and producing an immense pressure; for when the pressman first takes the handle, it acts with but little advantage as to power upon the levers, and therefore brings the platen down very quickly upon the tympan. The levers have then assumed positions, in which they exert a more powerful action upon each other; and this action continues to increase until one of the levers and its connecting rod come nearly into a line, when the power is immensely great, and capable of producing any requisite pressure. For fastening the types upon the table, or what the printers call the making register, instead of quoins or wedges being introduced at the angles in the usual manner, screws are fitted through pieces which are fixed to the sides of the table; and between the points of these screws the form of types is held steady upon the table, and may be adjusted.

We have not had an opportunity of trying a large press of this kind, but think it promises so much in saving of power and time, as to deserve a trial by printers. It avoids the moving of the heavy carriages with the form; for the platen need be but a small portion of the weight of the loaded carriage; and further, it is adapted to be moved from off the types sideways, and therefore has a less distance to move than the carriage in the ordinary press. The machinery is well contrived in all its parts, both for performance and stability, and is adapted to be made of iron, that it may have no yielding parts. It is far cheaper than the Stanhope press.

A *PRINTING-HOUSE* is a place destined for printing, and fitted up for that purpose with presses, cases, and other furniture.

The most considerable printing-houses in the world are those of the Louvre and Vatican. The first, begun under Francis I., was carried to its utmost perfection under Lewis XIII., by the care of cardinal Richelieu; and removed into the galleries of the Louvre by Lewis XIV.

The Vatican printing-house, called also the *Apostolical* printing-house, because the pope's bulls, decrees, &c. are printed in it, was begun by Pius IV., and furnished with great magnificence by Sixtus V. See VATICAN.

Out of both these printing-houses have come forth very beautiful and splendid editions of the ancient authors. The Vatican was the first that printed books in the Arabic language.

PRINTING, Stereotype, is a method of producing plates from moveable types, by forming a mould with them in plaster of Paris, or any other fit substance, and in this mould casting a metallic plate, which will have the same surface as the types had, and will print the same. Therefore, in this method the moveable types are not used to print from, (except for proofs to correct the errors of composition,) but are employed as a model or pattern to cast the

stereotype plates by which the impression is to be printed. For the history and further particulars of this invention, see STEREOTYPE.

PRINTING Machine.—The immense number of books and newspapers which are printed in this country, has rendered it desirable to have machines for printing, which would throw off copies more rapidly, and without requiring such excessive labour as the printing press does. For daily newspapers in London expedition is the grand object, as the whole impression (often as many as 6 or 8000 copies) must be printed between the hours of midnight, and eight or nine o'clock in the morning; and often, when there are important debates in parliament, they are not able to begin printing so soon as midnight.

The first attempts at printing machines were only to employ machinery for actuating a common press, and by the force of horses, or steam-engine, to perform the part of the pressman. We have seen a model of such a machine, which printed very well, and with great rapidity, but was so complicated, that on a large scale it could not have been urged into motion so quickly as the pressman can work; and in effect, when put to trial, it was found to employ one horse instead of one man to work the press. In 1790, Mr. Nicholson took out a patent for a machine to print by cylindrical rollers, the types being so formed with stems smaller at one end than at the other, that, when composed, they would form a cylindrical surface instead of a plane. Between a roller covered with these types, and another plain roller, the paper was to be passed, and thus receive an impression: the ink was distributed by machinery. Mr. Nicholson's machine answered very well for printing patterns upon calico, paper-hangings, or any other papers, where the surface of a solid roller could be engraved to print from; but the moveable types were not found practicable, and therefore the machine was inapplicable to book-printing.

A patent has recently been obtained by Messrs. Bacon and Donkin, for a machine which they publicly exhibited before the university of Cambridge, and they are now making one for printing bibles and prayer-books at the university. We have examined their machine at work, and found it to display so much mechanical ingenuity, and to produce such beautiful specimens of printing, with a rapidity unequalled by any other means, that we have made a drawing of it. (See *Plate III. Printing*.) The invention consists in adapting the types to be fixed upon, and form the surface of, a prismatic roller, such as a square, pentagon, hexagon, octagon, or other figure, and mounting this in a frame, with the means of turning it round upon its centres; a second roller is applied in such a manner, that its surface will keep in contact with the surface of the types which are inked, and the machine being put in motion, the paper which is to be printed is passed through and receives the impression. The types are inked by a cylinder, which is applied to revolve with its surface in contact with them. By this invention, the advantages of types between rollers are obtained, although the types are imposed upon plain surfaces.

Plate III. of Printing, contains a perspective view of a machine, the prism, A, of which is square in its section, and has the ordinary types or letter press applied upon its four sides, and firmly attached to it. The pivots at the end of the axis of this prism are supported in the frame B B, and it is caused to revolve, by a connection of wheelwork, D E and F G, from the winch and fly-wheel at H. The types upon its surface are caused to print upon the paper by means of a second roller, I i, called the platen, placed immediately beneath the former, and its surface being formed

to a particular curvature, produced by four segments of cylinders, its circumference, when it turns round, will always apply to the surface of the types, and thus a sheet of paper being introduced between them will receive the impression. The ink is applied to the types by means of a cylinder, K K, placed above the prism. It is composed of a soft elastic substance; and that its surface may always apply to the types, its spindle is fitted in pieces L, L, which moving upon an axis, *n*, permit the cylinder to rise and fall, to accommodate itself to the motion of the types. The ink cylinder receives its ink from a second cylinder, M M, which is called the distributing roller, also composed of a soft substance, and is supplied with ink by a third ink roller N N, which is made of metal, and extremely true. The ink is lodged in quantity against this roller upon a steel plate, O O, the edge of which, being placed at a very small distance from the circumference, permits the roller, as it revolves, to carry down a very thin film of ink upon its surface, and this being taken off by the distributing roller, is applied to the surface of the inking cylinder, which, as before-mentioned, inks the types.

The sheet of paper is introduced, as shewn in the figure, by placing it upon a blanket, which is extended upon a feeding-board P P, and drawn into the machine at a proper time, by having a small ruler, 2, fixed to it. The ends of this are taken forward by two studs, *b*, attached to endless chains, which are extended from the wheels, *e*, *e*, at the end of the platen, to other wheels, *d*, *d*, which are supported in the frame of the feeding-board. The wheels, *e*, *e*, having teeth entering the links of the chains, cause them to traverse when the machine is turned round, and at the proper time the pins, *b*, draw the ruler, 2, and blanket forward, and introduce the paper into the machine, and by passing between the prism and platen, it is printed as before-mentioned. This is the general action of the machine, and we shall proceed to detail the structure of the several parts. The type is composed, and made up into pages, in the usual manner; the pages are then placed in frames or galleys, *u*, *u*, and fastened by the screws at the ends, the shape and size of the galleys being adapted to the size of the page it is intended to print. These galleys are attached to the four sides of the central axis of the prism by the screw-clamps *i*, the edges of the galleys being mitred together. By relieving the clamps the galleys can quickly be removed, and others put in their places. The platen, I *i*, is composed of four segments of cylinders, *i*, *i*, which are attached to the different sides of the central axis, I, by means of screws, and these segments being proportioned to the prism, will be the true figure for the platen to produce the required motion, so that the surface, when it revolves, will, in all positions, preserve an accurate contact with the surface of the types. The two wheels, D, E, which cause the prism and platen to accompany each other, are formed to correspond with the two. Thus the upper wheel, D, is a square, with its angles rounded off, and the pitch or geometrical outline is exactly of the same size as the square formed by the surfaces of the types. The lower wheel, E, is of the same shape as the platen, and its pitch line the exact size of the surface thereof. These wheels being cut into teeth, as the figure shews, will turn each other round, and make their surfaces at the point of contact exactly correspond in their motions, so as to have no sliding or slipping upon each other. To regulate the pressure upon the paper, the bearings in which the pivots of the platen are supported, can be elevated by screws, 3, and its surface will press with more force upon the types; but that this may not derange the action of the wheels, D and E, universal joints are applied in their

axes at R. The inking cylinder, K, is caused to preserve its proper distance from the centre of the prism by wheels, S, fixed upon its axis, and resting upon shapes, T, fixed upon the axis of the prism. Each of the shapes, like the wheel D, has four flat sides, corresponding in size with the surfaces of the types; the angles are rounded to segments of a circle from the centre: the wheels, S, are of the same size as the inking cylinder, therefore, as they rest upon the shapes, T, they prevent the ink cylinder pressing upon the types with any more than a sufficient force to communicate the ink without blotting. The inking cylinder is turned round by a cog-wheel, V, upon the extremity of the axis of the prism, which is of the same shape as the wheel, D, and engages another wheel, W, upon the end of the spindle of the inking cylinder: the latter wheel likewise gives motion to the distributing roller by a pinion, *f*, and this again turns the ink roller by a third pinion, *g*, fixed upon the end of its axis, *n*, which is supported upon bearings, B, B, in the frame. The pieces, L, L, which support the pivots of the distributing roller and inking cylinder, are fitted upon the axis, *n*, of the inking cylinder, so as to rise and fall upon its centre, and the distances of the rollers being thus kept invariably the same, their circumferences are kept accurately in contact, to communicate the ink to each other. The steel plate, O, which, as before-mentioned, regulates the quantity of ink that the roller, N, shall take round with it, is supported by a piece extended across the fixed frame, B B. There are pieces of metal fixed upon this plate by thumb nuts, which prevent the ink flowing off at the ends, and they enter into grooves formed round the ink roller, N, near its ends. The machine is put in motion by the handle with the fly-wheel H, and this has a small wheel, G, turning a large one, F, upon the end of the axis *l*.

The frame supporting the feeding-board, P, consists of two rails, X, fitted upon the axis of the platen, and supported at the opposite ends by a brace from the framing; they sustain the pivots of the wheels, *d*, *d*, for the chains; *x* are two rulers fixed at each side of the feeding-board, and forming a lodgment for the ends of the ruler 2, which is attached to the blanket, and it slides upon these when it is advanced by the chains. The spaces on the platen between the segments, *i*, *i*, are all filled up by pieces of wood, except one, and in this space the ruler is received when it passes through the machine. In the interval when the spaces between the types are passing over the sheet, and therefore leave the margin between the pages of printing, the paper is not held between the rollers; but to prevent it from slipping during this interval, the blanket and paper are pressed down upon the pieces of wood which fill up in the platen between the segments, *i*, *i*, by the weight of small rollers or wires, 4, supported by cocks, 5, projecting from the axis of the prism, and being fitted into the slits at the end of these cocks. The wires are at liberty to rise and fall by their own weight; thus, when they are at the upper part of the revolution, they fall into the spaces at the angle of the prism, between the pages of the types, and thus escape the ink cylinder; but when they are at the lower part of their revolution, they fall upon the paper, and press it with sufficient force upon the pieces of wood in the platen to carry the paper forward at the interval when the types do not act upon it, and of course while the space between the pages of the printing is passing through.

The operation of printing being very delicate, and requiring great accuracy, the machine is provided with many adjustments to make it act correctly, which are as follow: The segments, *i*, *i*, upon the platen roller are attached to the central axis, I, by three screws at each end; the two

middle ones of these (represented with square heads) draw the segments down upon the central axis, whilst the others (which are turned by a screw driver) bear them off; therefore, by means of these screws, the segments can be accurately adjusted, till they are found by experiment to apply correctly to the types, and make an equal impression on all parts of the sheet. To render the whole impression greater or less, the screws, 3, beneath the bearings of the platen roller are turned as before-mentioned. The degree of pressure with which the ink roller bears upon the types, is regulated by increasing or diminishing the size of the shapes, T, which support its weight. And to render these capable of adjustment, each is composed of four pieces, marked 6, attached by screws, 7, to a central piece, or wheel, which is fixed upon the axis; and as the edges of these pieces form the outline of the shape, they admit of being adjusted by other screws to a greater or less distance from the centre, and of course may be made to bear up the ink cylinder, till the pressure on the types is equal throughout the whole surface, and sufficient to supply the ink properly. The ink cylinder is adjustable as to its pressure against the distributing roller, and for this purpose the bearings, k, which support the cylinder, are fitted upon the pieces, L, to slide, being capable of regulation by means of screws. In a similar manner the distributing roller can be adjusted to a proper distance from the inking cylinder. The plate, o, can be adjusted for the distance from the ink roller, N, by screws, p, fastened by thumb nuts: this regulates the degree of colour the impression will have, by permitting the roller, N, to take more or less ink: behind the inking cylinder, K, a rubber, or scraper, is placed, to press very lightly against the cylinder, and to prevent the ink accumulating, in rings, round the cylinder; it is fitted upon centres, and held up by a lever, which is suspended by a catch, y, at the end of the piece L. This catch is withdrawn when the machine is not at work, and then the scraper falling down upon its centre, does not touch the cylinder. It is necessary that the wheels D and E should be placed upon their axes, in such a position that their curvature will correspond with the curvature of the prism and platen. For this purpose the universal joint, R, is fitted upon the axis, l, of the wheel, with a round part, that it may turn on it. A piece of metal, r, is fixed fast upon the spindle, l, and has a hole in it for the reception of a tooth, s, which is screwed fast upon the universal joint; then two screws being tapped through the sides of the piece, r, press upon the end of s, and by forcing it either way, will adjust the wheel with respect to the platen, till they exactly correspond: another similar adjustment may be applied to the upper axis.

The manner of forming the inking and distributing rollers with an elastic substance, is worthy of particular notice. Leather stuffed in the manner of a cushion was first used, but did not succeed, because it became indented with the types; but after many trials, a composition of glue, mixed with treacle, was found to answer perfectly. The roller is made of a copper tube, covered with canvas, and placed in a mould, which is a cylindrical metal tube, accurately bored, and oiled within: the melted composition is then poured into the space of the mould, and when cold, the whole is drawn out of it, with the glue adhering to the copper tube, and forming an accurate cylinder without any farther trouble. The composition will not harden materially by the exposure to air, nor does it dissolve by the oil contained in the ink. This machine is well adapted to print from stereotype plates, which the universities have adopted for their bibles and prayer-books.

We understand that a printing machine will very soon be

produced by Mr. Bensley, which is the invention of a foreigner, who has taken several patents for it, but we have not yet had an opportunity of seeing one.

Printing Machine for numbering Bank Notes.—This machine is ingenious and curious, from the circumstance, that after every impression which is produced by it, the types are changed by mechanism, so as to produce a different impression the next time. The Bank of England have, within these few years past, adopted this method of filling up the blank spaces which are left in their notes after they have been printed from a copper plate by the rolling-press. These blanks, which are for the number and date of the note, were formerly filled up in writing; for each note being different in these particulars did not admit of being printed, until the present machine was invented by Mr. Joseph Bramah. The note which is engraved on the copper plate, and printed, is as follows.

Bank of England, 1814.

*I Promise to pay to Mr. Henry Hefe or Bearer
on Demand the Sum of Ten Pounds*

Ten

*For the Gov. and Comp.
of the Bank of England.*

Upon these notes the machine is required to print the number twice repeated, which is first to be printed, in large characters, upon the word *I Promise*, in the first line, and again upon the words *or Bearer*, at the end of the same; as, for instance,

N^o 13462

1814 March 11. London 11 March 1814.

London and the date are printed in the blank line which is left after the words, *Sum of Ten Pounds*.

The copper plates on which the above is engraved are double, that is, each prints two notes upon one long piece of paper, which being put into the machine, has the blanks printed in the easiest manner imaginable. In the operation of taking out the paper to put in another note, the machine changes the types to the succeeding number: for instance, if one of the notes is printed N^o 10 N^o 10, and the other upon the same paper, N^o 100 N^o 100, when the paper is taken out, the types change, without any attention of the operator, to N^o 11 N^o 11, and N^o 101 N^o 101, and when these are printed, they change again to the succeeding numbers. The types for the date are cast in stereotype, and are of course changed every day, each machine being furnished with one for every day in the year.

The advantages of this method have been found considerable, in avoiding mistakes of numbering notes erroneously, to which they were before very liable, and in the dispatch of business, its advantages are very great. To fill up 400 notes, with the number and date twice repeated, was considered a sufficient day's labour for each clerk; but by the machines, one man can print 1300 double notes, which are equal to 2600 single ones, or perform more than six times the business which could formerly be done in the same time. The

Bank of England have more than forty of these machines, one of which we have obtained drawings from; but to diminish it to the size of a plate, our draughtsman has represented it as if cut in half, or made as a single machine, to print only one note at a time; those in use at the Bank are therefore to be considered as double the length, and containing a repetition of the types and the machinery for moving them. In *Plate II. Printing, fig. 1.* is a section, and *fig. 2.* a plan, and the same letters refer to both. The whole is framed upon a thick board of mahogany, which is fastened down upon a table: the frame, which is of iron, is screwed to the board at *L*, and forms a square box, in which the mechanism is contained. *K K* is a brass lid, or cover, to the box, through holes in which the types, for printing the numbers, are placed, and their surfaces project a little above the surface of the cover, *K*, so as to produce an impression when the note is pressed down upon them by the power of the hand applied to the lever *D*. This lever moves upon an axis *A*, (*fig. 1.*) which extends across the box, having pivots fitted into sockets, *B*, (*fig. 2.*) projecting up from the frame, as is evident in the figure. From this axis a piece of metal, *C*, extends, and has screws, *l* and *m*, in it, by which the tablet, or platen, *E*, is attached to it; and these screws admit of adjusting the tablet, *E*, with respect to the axis, that its under surface may fall perfectly flat upon the types, and print with equal pressure upon all parts of the note. For this purpose four of the screws, *m*, pass through holes in the piece *C*, and screw into the tablet, so as to draw the two together; whilst the other two screws, *l*, screw into the piece *C*, and their points bear upon the upper surface of the tablet, *E*; it is therefore by the latter that the pressure is transmitted, the others being only for adjustment: the lever *D D* is fastened upon *C* by three screws, marked *n, o, o*. The note is placed upon the under surface of the tablet, *E*, when it is to be printed, its situation being determined by two fine pins fixed in the tablet, which are made to penetrate the paper at two small dots printed upon it by the copper-plate which printed the words of the note, as before-mentioned; and it is confined in its position against the tablet by the frisket, which is a piece of vellum, *H*, stretched in a brass frame, and is connected by hinges, *a, a*, to the tablet *E*; it thus folds down, enclosing the note between the tablet and frisket as it were in a book. The vellum of the frisket has openings cut through it at the places where the machine is to print upon the note. As it is necessary that the paper should be pressed upon the types by a yielding substance, the tablet, *E*, has two folds of cloth placed against its surface, and these are secured by a piece of parchment, stretched over a brass frame, which is attached to the tablet by four screws. The note therefore is placed against this parchment when it is to be printed; and not against the brass of the tablet. Each circle, as shewn in *fig. 6*, has its circumference divided into 11 cogs, and in every cog a space is cut to receive one of the types which are arranged round the cogs, in a series of 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, and a blank; and as the circles are placed close together, and turn round independent of each other, any combination of figures may be made by them which is less than N^o 99,999, beyond which number the bank-notes have not extended. Each of the circles has a tendency given it to assume the position in which the types are proper for printing; that is, with their upper surface parallel to the brass plate *K*, by means of a small pin fitted into a hole in the axis *F*, and having a constant pressure outwards by a small spiral spring placed in the hole beneath it. This pin comes to rest in an angular notch made within the

circle, opposite each type, as shewn by the dark shaded parts in *fig. 6*, and each circle is provided with one of these pins. The end of the pin is formed spherical, and well polished, so that when the circle is turned round, it is forced into its hole in the axis *F*; but when another notch in the circle presents itself, the pin presses out into it, and retains the circle with a moderate force in its proper position, but will not allow it to rest, except when the pin is in the notch. The word London and the dates are cast in stereotype, and are fastened down upon the surface of the cover, *K*, of the box, just beneath the letter *E*, in *fig. 1*. The dates are changed every day; the catch, by which they are fastened on the plate, being very readily withdrawn; but when thrown up, holds them sufficiently fast. The types for printing the numbers are moveable, and herein the invention consists; they are fixed in the circumferences of wheels, or circles, *d, d*, (shewn also at *e, e*, in *fig. 3*, where the types are plainly pointed out by the numerals upon them); these circles are ten in number, and are divided into two clusters, one at each end of the spindle, or axis, *F*, upon which they all revolve freely. This axis, when in the machine, as at *F*, (*fig. 1.*) extends across the frame from side to side, and the types fixed in the circles project above the surface of the cover, *K*, passing up through holes made in the same, as is evident from the figure. By this means the types always arrange themselves into a straight line, and also with their surfaces parallel to the surface *K K*, without which they would not print equally upon the paper. From this description, our readers will perceive that the machine has the power of printing any numbers, or series of numbers, containing less than five figures, by turning the circles round one tooth every time after an impression has been taken, so as to bring a succeeding type into action. But the machine is rendered very complete, by the addition of the following mechanism, to give motion to the circles. A catch or click, *b*, is fixed upon the axis, *A*, of the platen, and acts in the teeth of a wheel, *H*, fixed upon an axis, *G*, (see also *fig. 4.*) which is extended across the machine, and the teeth of other similar wheels, *H* and *K*, (*fig. 4.*) enter into the spaces between the types in the circles *d, d*, as seen in *fig. 1*, and thus, when the axis, *G*, is turned round, it communicates a corresponding motion to some of the circles. The click, *b*, is fixed on the axis, *A*, in such a position, that it does not operate upon the teeth of *H*, except when the handle, *D*, is lifted up, or rather thrown back, as far as it will go, which is regulated by pieces screwed upon the axis coming in contact with the stops fixed upon the plate *K*; and in doing this, the catch, *b*, moves the wheel, *H*, round one tooth, and consequently the wheel *d*, so as to bring up another type.

The operator, in using the machine, first inks the types with a small printer's ball, opens the frisket sheet, *H*, upon its hinges, *a*, and places the note against the tablet, the proper place being determined by the dots and pins before-mentioned. He now shuts up the frisket, and encloses the note between it and the tablet, the frisket sheet having holes cut through it at the places where the note is to be printed. The handle, *D*, is now brought down to give the impression; but in this, it should be observed, that though the catch, *b*, again meets the tooth of the wheel *H*, it has no effect upon it, being fitted upon a joint, so as to give way in this direction, and it passes by without moving the wheel. The pressure for printing is given in an instant, and the handle, *D*, being then lifted up to remove the note, and place a fresh paper upon the tablet, the catch, *b*, moves the wheel, *H*, one tooth; and as these engage the teeth of

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the circles, *d*, they are turned likewise to change the types ready for printing the succeeding numbers.

We have now to explain the order in which the change of the numbers is conducted. The wheels, H and K, (*fig. 4.*) are only intended to operate upon one of the five circles at the same time; but by sliding the axis, G, endways in its bearings, they can be made to act upon any one of the five which is required; and in all cases the distance between the two wheels, H and K, is such, that they will operate upon the same circle of the assemblage, at either end at the same time. The axis, G, can be retained in any required position by a semi-circular clip, which enters into grooves, *e*, (*fig. 4.*) formed round the axis, and there are five of these, corresponding with the different positions of the axis proper for the wheels to act with the several circles. The shifting of the axis is performed by the knobs at the ends of the spindle, G, which come through the sides of the box, the semi-circular clip which retains it being first lifted up, by turning a knob, *k*, which operates upon it. When the printing first begins, the circles, *d*, are turned round by means of a wooden skewer, so that all the blank types are brought up at the same time. The axis, G, is next set, so that its wheels, H and K, are engaged with the right-hand circle of each of the assemblages of five at each end. In this situation, if the handle, D, is moved down, in raising it up again, the catch, *b*, moves the wheels round, and brings up N^o 1 N^o 1 of the types, and a note being printed with this, in lifting up the handle N^o 2 is brought up. Another note is now printed, then N^o 3, and so on, till N^o 9 is printed, and 0 brought up; after which, the handle is brought down twice without printing any note. This brings up the blank space and N^o 1. The axis is now shifted by its knob Q, (*fig. 1.*) to act upon the second circle from the right-hand, and one motion of the handle being made, brings up 0 of the second circle, making 01 N, which, when printed, (types being always in reverse,) will be N^o 10. The first circle to the right-hand, which before was units, is now become tens, and the second units, which therefore shifts, at every impression, to 11, 12, &c. up to 19; and after printing this the 0 comes up, making 10. The first right-hand circle is then pushed forwards by the printer by a small wooden skewer, and 2 brought up, making 20. In this manner it proceeds, changing the first circle by hand at every ten, the machine altering itself at every unit, till 99 are printed. When 100 is to be printed, the axis, G, is shifted to the third circle, which becomes units, the second, tens, and the first, hundreds. The printing then proceeds as before, the units being advanced by the machine, but the tens and hundreds, as often as they require it, are advanced by hand. At 1000 the axis is shifted to the fourth circle, and the denomination of each is changed by this becoming the unit: three circles must now be moved by hand, as often as they require it. On arriving at 10,000, the fifth circle must be made unit, by shifting the axis to it, and the four first are moved, when necessary, by hand, and in this manner the machine will print up to 99,999, which is 100,000, wanting 1.

PRINTING, Chinese. There are three opinions as to the antiquity of the Chinese printing: one fixing it three hundred years before Christ; another nine hundred years after him; and a third carrying it still farther back, and making it coeval with that mighty empire; though, it must be allowed, the last is much the least probable of the three.

The manner of printing we have already hinted to be very different from that which now obtains among the Europeans. It is true, it has some advantage over our's in correctness, and the beauty of the character; but, in other respects, it

comes far short, the single advantage of moveable characters making more than amends for all that is urged against us by some zealous advocates for this oriental printing.

Books are printed in China from wooden planks, or blocks, cut like those used in printing of calico, paper, cards, &c. among us.

These blocks are made of a smooth, firm, close wood, and of the size of the leaf required. On the face-side they glue a paper, upon which some able penman draws out the several letters and characters with a Chinese pen, which is a kind of pencil. This is the principal part of the work, and that on which the success of the rest depends.

When finished, the block is put into the hands of a sculptor, or cutter in wood; who, following the several strokes of the writer with his gravers, and other sharp little instruments, makes them all appear in relief on the wood. When the carving or cutting is finished, they moisten what remains of the paper, and rub it gently off.

The ink they use in printing is the same with the common Chinese ink, with which they also write, and is made of lamp-black, mixed up with other ingredients.

Their press resembles our rolling-press much more than the letter-press.

As to their paper it is inferior to our's: it is made of the inner bark or rind of a kind of rushes, beat up with water into a pulp or paste, and formed in moulds, much like our's. See PAPER.

The advantages of the Chinese printing consist in this, that they are not obliged to take off the whole edition at once, but print their books as they need them; that the blocks are easily retouched, and made to serve afresh, and that there needs no corrector of the press.

Its disadvantages are, that a large room will scarcely hold all the blocks of a moderate volume; that the colour of the ink easily fades; and that the paper is apt to tear, and is subject to worms: whence it is, that so few ancient books are seen in China.

PRINTING, Rolling-Press, is employed in taking off prints or impressions from copper-plates engraven or etched.

It differs, as we have before observed, from letter-printing, in that the marks and characters, whose impressions are to be taken, in the former case are indented, or cut inwards; and in the latter are in relief, or stand out.

This art is said to be as ancient as the year 1460, and to owe its origin to Finiguerra, a Florentine goldsmith; who, casting a piece of engraven plate in melted brimstone, found the exact print of the engraving left in the cold brimstone, marked with black licked out of the strokes by the liquid sulphur.

Upon this, he attempted to do the same on silver plates with wet paper, by rolling it smoothly with a roller; and this succeeded.

This novelty tempted Baccio Baldini, a goldsmith of the same city, to attempt the same; which he did with success, engraving several plates of Sandro Boticello's design, and printing them off in this new way; in which he was followed by Andrew Mantegna, then at Rome.

This knowledge getting into Flanders, Martin of Antwerp, a famous painter, graved abundance of plates of his own invention, and sent several prints into Italy, marked thus, M. C. After him, Albert Durer appeared, and gave the world a vast number of prints both in wood and copper. About this time, one Hugo de Carpi, an Italian painter, found out a way, by means of several pieces of wood, to make prints resemble designs of chiaro-scuro (see CUTTING in Wood); a method revived in our country, some years ago, with much success by Kirkall, and since at Venice by

Jackson, though very imperfectly; and some years after, the invention of etching was discovered, which was soon after made use of by Parmeggiano.

Mr. Walpole observes, that it was not till Raphael had formed Marc Antonio, that engraving placed itself with dignity by the side of painting. See ENGRAVING and ETCHING.

When the art reached England does not certainly appear. Mr. Chambers, on the authority of Mr. Bagford, (see Phil. Transf. N° 310. p. 2397, or Abr. vol. v. part ii. p. 20.) erroneously said, that it was first brought from Antwerp by Speed, in the reign of James I.; whereas we had it in some degree almost as soon as printing; the printers themselves using small plates for their devices and rebuses. Caxton's Golden Legend, printed in 1413, has in the beginning a group of saints, and many other cuts disposed through the body of the work. The second edition of his Game of Chefs, and Le Morte de Arthur, had also cuts. Wynkyn de Worde, Caxton's successor, prefixed to his title of the Statutes, in the seventh year of Henry VII. or 1491, a plate with the king's arms, crests, &c. a copy of which is given in the Life of Wynkyn, by Mr. Ames, in his Typographical Antiquities, p. 79. The same printer exhibited several books adorned with cuts, some of which are particularly described by his biographer, p. 87, 88, 89, &c.

The subsequent printers continued to ornament their books with wooden cuts. One considerable work, published by John Rastell, called the Pastyme of the People, and Rastell's Chronicle, was distinguished by prints of such uncommon merit for that age, as to have been ascribed to Holbein. Grafton's Chronicle, printed in 1569, contained many heads, as of William the Conqueror, Henry VIII., queen Elizabeth, &c. and many more are recorded by Ames. But though portraits were used in books, Mr. Walpole observes, that he can find no trace of single prints being wrought off in that age. Those which composed part of the collection of Henry VIII. were probably the productions of foreign artists. The first book that appeared with cuts from copper-plates, or at least the first that Mr. Ames had observed, was the Birth of Mankind; otherwise called the Woman's Book, dedicated to queen Catharine, and published by Thomas Raynalde in 1540, with many small copper cuts, without any name. See Ames, ubi supra, p. 35. 46. 60, and 219. Walpole's Catalogue of Engravers, &c. 4to.

The fabric of the rolling-press, and the composition of the ink used in it, with the manner of applying both in the taking off prints, are as follow:

Structure of the Rolling-Press.—This machine, like the common press, may be divided into two parts: the *body* and *carriage*, analogous to those in the other.

The body consists of two cheeks of different dimensions, ordinarily about four feet and a half high, a foot thick, and two and a half apart, joined at top and bottom by cross pieces. The cheeks are placed perpendicularly on a wooden stand or foot, horizontally placed, and sustaining the whole press.

From the foot likewise rise four other perpendicular pieces, joined by other cross or horizontal ones; which may be considered as the carriage of the press, as serving to sustain a smooth, even plank, which is about four feet and a half long, two feet and a half broad, and an inch and a half thick; upon which the engraven plate is to be placed.

Into the cheeks go two wooden cylinders or rollers, about six inches in diameter, borne up at each end by the cheeks, whose ends, which are lessened to about two inches

diameter, and called *trunnions*, turn in the cheeks between two pieces of wood, in form of half-moons, lined with polished iron, to facilitate the motion.

The space in the half moons, left vacant by the trunnion, is filled with paper, pasteboard, &c., that they may be raised and lowered at discretion; so as only to leave the space between them necessary for the carriage of the plank charged with the plate, paper, and blankets.

Lastly, to one of the trunnions of the upper roller is fastened a cross, consisting of two levers, or pieces of wood, traversing each other. The arms of this cross serve in lieu of the handle of the common press; giving a motion to the upper roller, and that to the under one; by which means the plank is protruded, or passed between them.

Preparation of the Ink.—The ink used in rolling-press printing, is a composition of black and oil mixed and boiled together in a due proportion.

The black is a factitious matter, made, as some suppose, of the oil of vine twigs, or, according to others, of the kernels of fruits, such as peaches and apricots, well burnt, with wine lees.

This black is usually brought hither ready prepared from Frankfort on the Maine; whence our printers call it Frankfort black.

This is softer and more free from grittiness than the ivory or other charcoal blacks, as they are usually prepared among us.

The oil with which they dilute this black is nut-oil; which is set on fire, boiled up differently, according to the different works it is to be used in; but never so far as to communicate to the oil the adhesive gluey quality of the printer's varnish.

They usually make three kinds, thin, thick, and strong, only differing in the degree of coction; the strong is that used in the finest works, &c.

To make the ink, they pulverize the black very carefully, and pass it through a fine sieve; then mix it up on a marble with the proper oil, by means of a mullet, after the same manner as the painters do their colours.

PRINTING from Copper-plates, Method of.—The ink being prepared, they take a little quantity of it on a rubber, made of linen rags, strongly bound about each other; and with it smear the whole face of the plate, as it lies on a grate, over a charcoal-fire.

The plate sufficiently inked, they first wipe it coarsely over with a foul rag, then with the palm of the left hand, then with that of the right; and to dry the hand, and forward the wiping, rub it from time to time on whiting. In wiping the plate perfectly clean, yet without taking the ink out of the engraving, consists a great part of the address of the workman. The French printers use no whiting, as being detrimental to the colour of the ink; nor do they lay the plate on the grate to warm, till after inking and wiping it.

The plate, thus prepared, is laid on a thick paper, fitted upon the plank of the press; over the plate is laid the paper, first moistened, to receive the impression; and over the paper two or three folds of blanketing, or other stuff.

Thus disposed, the arms of the cross are pulled, and, by this means, the plate, with its furniture, passed through between the rollers; which, pinching very strongly, yet equally, presses the moistened paper into the strokes of the engraving, whence it licks out the ink.

Some works require being passed twice through the press, others only once, according as the graving is more or less deep, or the greater or less degree of blackness the print is desired to have.

It must be observed, that the stronger and thicker the ink is, the stronger must the rollers pinch the plate; this tempts many of the workmen to use a thinner oil, in order to save labour; which proves very prejudicial to the impression.

The wetting of the paper ought to be done two or three days before printing it, to render it more supple and mellow: as the prints are drawn off, they are hung up to dry on lines, &c.

Lastly, after the number of prints desired have been wrought off from the plate, they rub it over with oil of olives, to prevent its rusting, and set it by against a new impression. If the strokes of the graving be perceived full of ink hardened therein in the course of the printing, they boil it well in ley before the oil be applied.

PRINTING *with wooden prints.* See CUTTING in *Wood*.

PRINTING in *chiaro-scuro*, is a method of producing a strong effect of relief, attended with a just and natural gradation of the lights and shades, grounded with brown, with white and black, by printing on paper. We have already observed, that the art of doing this in wood was discovered in Italy, by Hugo de Carpi. M. le Bossé directs it to be performed in the following manner. Having provided two copper-plates of equal size, and exactly fitted to each other, on one of them let the proposed design be engraved, and let the prints be taken off from it with printing ink

on sheets of grey paper. The other plate must then be varnished, and the varnished side being laid upon the sheet printed by the first plate, they must be passed under the roller; when the print will have made a counter-proof on the varnish of the plate; after which the lights must be graved on the plate, and corroded very deeply by aquafortis. The same thing may otherwise be done with the graver, and with greater ease by those who can use it well. In order to properly prepare the oil, the best method is to use very white nut-oil drawn without fire, and to put it into two leaden vessels, and set it in the sun till it becomes thick in the proportion of the weak oil. Flake white must then be taken, which must be ground, and washed over, till it be extremely fine; and then being dry, it must be ground with the weak oil, and the thick oil added to it. Then having taken an impression with black printing ink, or any other colour, from the first plate, that is entirely engraved, on coarse grey paper, it must be left to dry for ten or twelve days; when these prints having been wet, another impression must be made upon them by the plate, on which the lights are engraved, charged with the white flake and oil in the usual manner of printing; taking care that the correspondent parts of the plate, and the impression already made, may be adapted exactly. By this means the printing in *chiaro-scuro* is perfectly performed. See CLAIM *Ob/cure*.

The STANHOPE or IRON PRESS.

Fig 1 Elevation

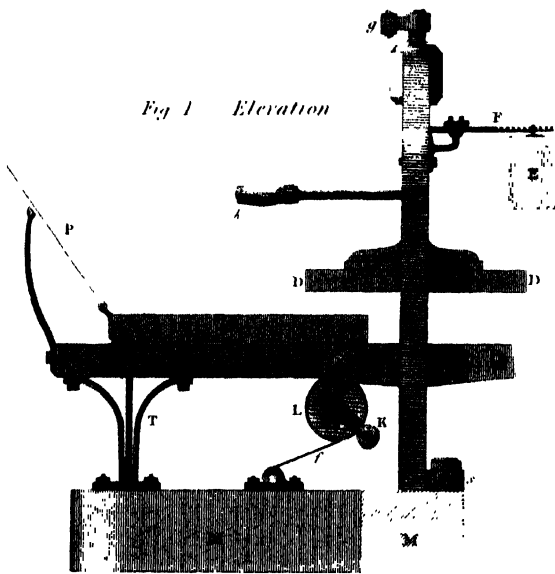


Fig 2.

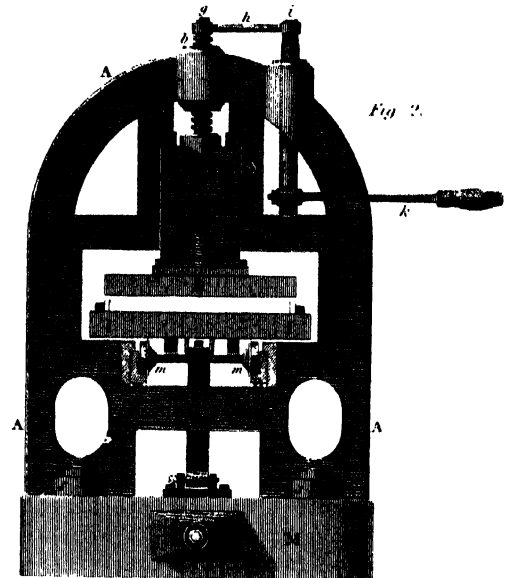


Fig 3 Plan

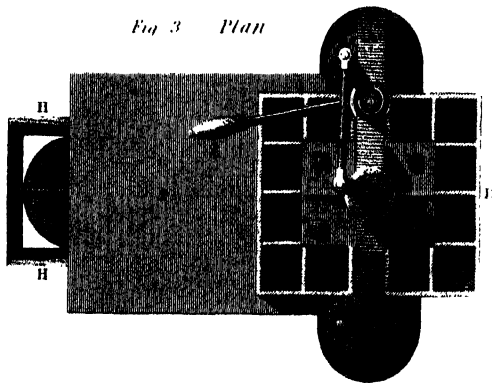


Fig 4 Section

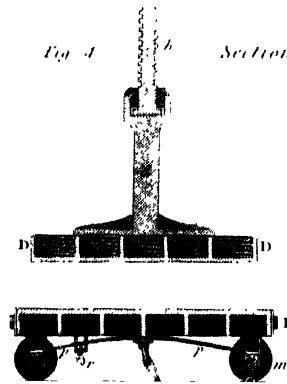


Fig 6

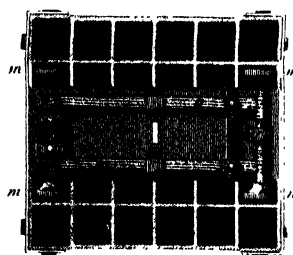
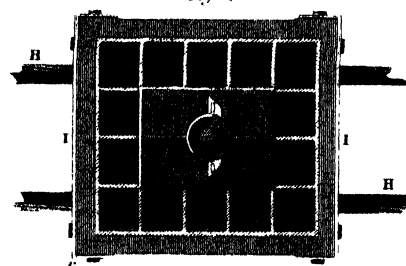


Fig 5

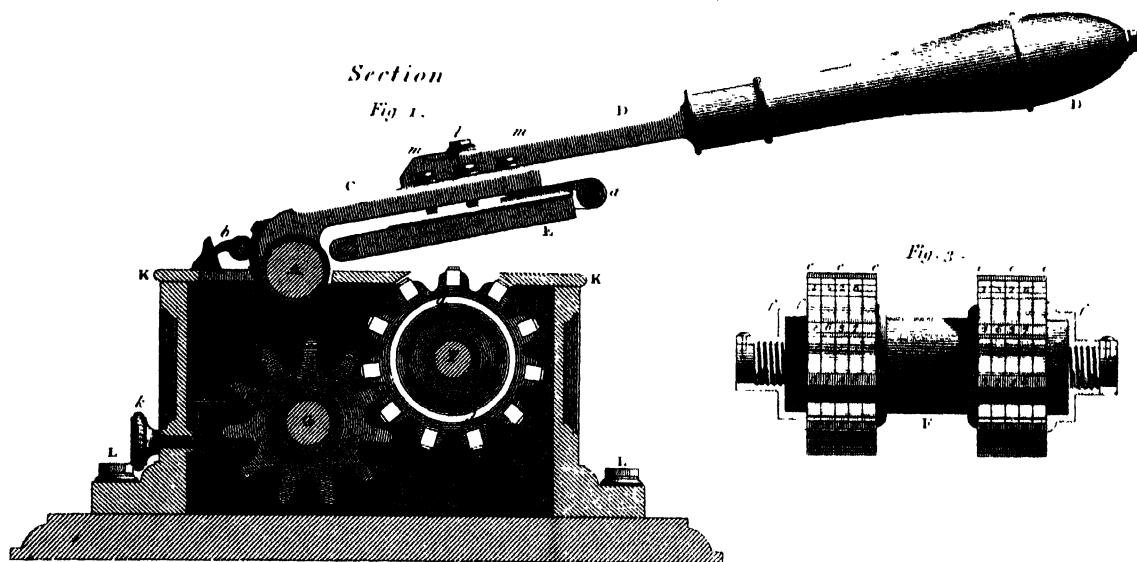


PRINTING.

Mr Bramah's Bank note Printing machine.

PLATE II.

1 2 3 4 5 6 7 8 9 10 11 12 Inches



Plan

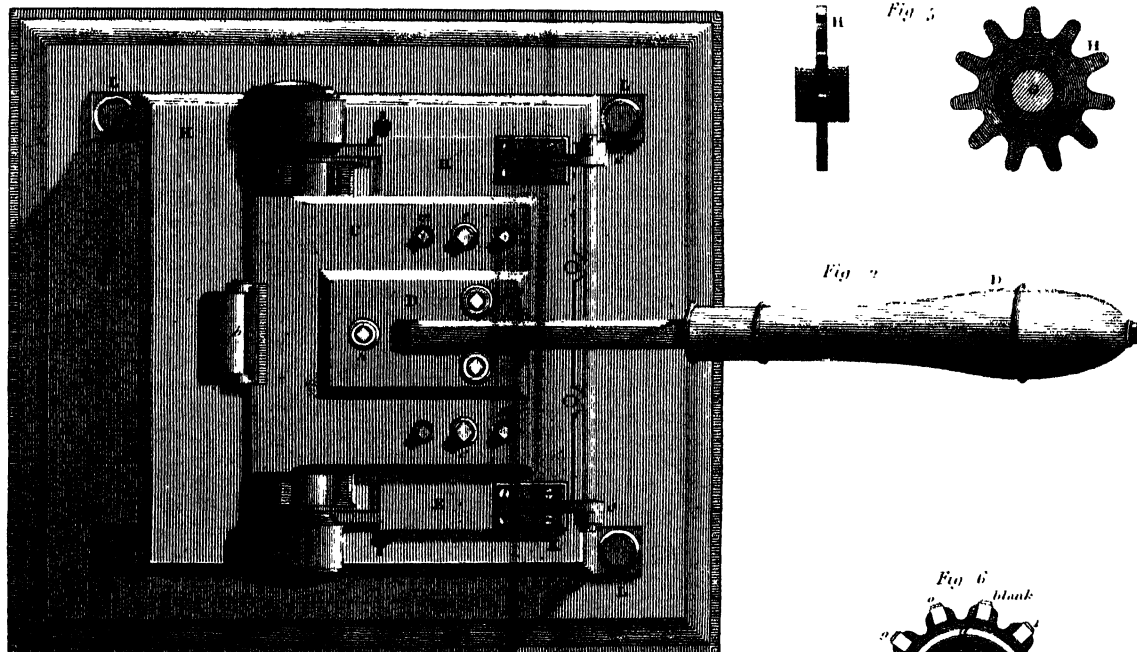
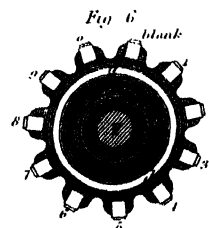
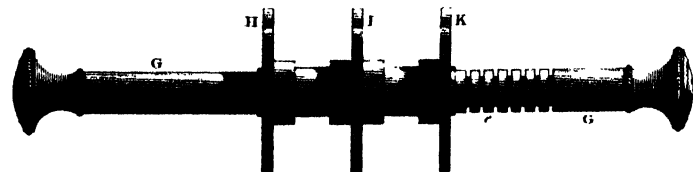


Fig. 4.



Pump

PUMP, ANTLIA, in *Hydraulics*, a machine formed on the model of a syringe, for raising of water.

Vitruvius ascribes the first invention of pumps to Ctesibius the Athenian ; whence the Latins call it *machina Ctesibiana*, or *organum Ctesibicum*.

Pumps are distinguished into several kinds, with regard to the several modes of their acting. As the

Common sucking-pump, which consists of a pipe open at both ends, in which is a moveable piston, bucket, or sucker, as big as the bore of the pipe in that part in which it works, and leathered round so as to fit the bore exactly ; and may

be moved up and down, without admitting any air to come between it and the pipe or pump barrel. There are several kinds of buckets: the most simple of all, which is commonly used for ordinary pumps, consists of a cylindric piece of wood, whose diameter is somewhat less than the bore of the barrel, that it may move in it freely, having a hole quite through the middle of it. Upon the top of this there is an iron piece fastened to a rod of iron or wood, which goes quite to the top of the pump, and by means of which the motion is given to the bucket. Near the top of the cylindric wood, there is a leather ring fastened round it, which goes a little higher than its top: the hole in the wood is stopped by a valve, made of a round piece of leather, fastened in one part of the wood with nails. Upon this there is an iron plate, a little larger than the bore of the hole, and another iron plate under it, a little less than the same bore; and the plates and leather are fastened together by means of a rivet or screw in the middle of them. When the bucket is put into the barrel, and the leather becomes wet, it will apply itself to the sides of the barrel, and prevent the passage of the air. The use of the two iron plates is to sustain the pressure of the water which would otherwise bend the leathers. For larger pumps, the bucket is made in the following manner: there is a hollow piece of brass, almost equal at top to the bore of the barrel, but small at the bottom, having at its top a brass bar, and at the bottom two notches to receive the ends of another brass bar, of the same figure as that at the top. Round the brass piece there goes a leathern ring, fastened to it at its lower part by means of an iron ring, which, being almost at the bottom of the brass piece, is not so large as its top, and consequently does not touch the sides of the barrel: this leathern ring should go a little higher than the cross-piece at bottom. The valve consists of a piece of leather almost equal to the top of the brass piece, covered by two iron plates of the same size as the leather, and having under it two plates somewhat smaller than the bore of the brass piece at its top; these iron plates and leathers are fastened together with screws. This valve must be applied to the top of the brass piece or box, so that the brass bar upon it may be between the two iron plates under the leather. The whole is fastened together by means of an iron piece, whose lower part goes through the holes in the middle of the valve, and the two brass rods, so that its upper part getting between the two upper iron plates of the valve, presses upon the leather, and makes it apply itself close to the upper brass bar. This iron piece or rod ought to have two holes, one at the bottom, just under the lower brass rod, to hold it close by means of a pin or key; and another at its top, to fasten it to another iron rod, which is continued quite to the top of the pump, in order to give motion to the bucket. The chief advantages of this kind of buckets are, that they give the freest passage to the water, having the least friction possible, as they touch the barrel only at the upper end of the brass box; and that the sand or gravel, which is commonly mixed with the water, cannot get between the bucket and the barrel, because the leathern ring is higher than the brass tube; besides, if by any accident the motion of one side of the valve were hindered, the other would serve till it were mended. See VALVE.

The construction of pumps is usually explained by glass models, in which the action both of the pistons and valves may be seen. In order to understand the structure and operation of the common pump, let the model DCBL (Plate XIV. *Hydraulics*, fig. 4.) be placed upright in the vessel of water K, the water being deep enough to rise at least as high as from A to L. The valve *a* on the

moveable bucket G, and the valve *b* on the fixed box H, (which box quite fills the bore of the pipe or barrel at H,) will each lie close, by its own weight, upon the hole in the bucket and box, until the engine begins to work. The valves are made of brass, and covered underneath with leather for closing the holes the more exactly: and the bucket G is raised and depressed alternately by the handle E and rod D *d*, the bucket being supposed at B before the working begins.

Take hold of the handle E, and thereby draw up the bucket from B to C, which will make room for the air in the pump all the way below the bucket to dilate itself, by which its spring is weakened, and then its force is not equivalent to the weight or pressure of the outward air upon the water in the vessel K: and, therefore, at the first stroke, the outward air will press up the water through the notched foot A, into the lower pipe, about as far as *e*: this will condense the rarefied air in the pipe between *e* and C to the same state it was in before; and then, as its spring within the pipe is equal to the force or pressure of the outward air, the water will rise no higher by the first stroke; and the valve *b*, which was raised a little by the dilatation of the air in the pipe, will fall, and stop the hole in the box H; and the surface of the water will stand at *e*. Then depress the piston or bucket from C to B, and as the air in the part B cannot get back again through the valve *b*, it will (as the bucket descends) raise the valve *a*, and to make its way through the upper part of the barrel *d* into the open air. But upon raising the bucket G a second time, the air between it and the water in the lower pipe at *e* will be again left at liberty to fill a larger space; and so its spring being again weakened, the pressure of the outward air on the water in the vessel K will force more water up into the lower pipe from *e* to *f*; and when the bucket is at its greatest height C, the lower valve *b* will fall, and stop the hole in the box H, as before. At the next stroke of the bucket or piston, the water will rise through the box H towards B, and then the valve *b*, which was raised by it, will fall when the bucket G is at its greatest height. Upon depressing the bucket again, the water cannot be pushed back through the valve *b*, which keeps close upon the hole whilst the piston descends. And upon raising the piston again, the outward pressure of the air will force the water up through H, where it will raise the valve, and follow the bucket to C. Upon the next depression of the bucket G, it will go down into the water in the barrel B; and as the water cannot be driven back through the now close valve *b*, it will raise the valve *a* as the bucket descends, and will be lifted up by the bucket when it is next raised. And now, the whole space below the bucket being full, the water above it cannot sink when it is next depressed; but upon its depression, the valve *a* will rise to let the bucket go down; and when it is quite down, the valve *a* will fall by its weight, and stop the hole in the bucket. When the bucket is next raised, all the water above it will be lifted up, and begin to run off by the pipe F. And thus, by raising and depressing the bucket alternately, there is still more water raised by it; which getting above the pipe F, into the wide top I, will supply the pipe, and make it run with a continued stream.

So, at every time the bucket is raised, the valve *b* rises, and the valve *a* falls; and at every time the bucket is depressed, the valve *b* falls, and *a* rises.

As it is the pressure of the air or atmosphere which causes the water to rise, and follow the piston or bucket G as it is drawn up: and since a column of water 32 feet high is of equal weight with as thick a column of the atmosphere,

from the earth to the very top of the air; therefore the perpendicular height of the piston or bucket from the surface of the water in the well must always be less than 32 feet; otherwise the water will never get above the bucket. But when the height is less, the pressure of the atmosphere will be greater than the weight of the water in the pump, and will therefore raise it above the bucket: and when the water has once got above the bucket, it may be lifted by it to any height, if the rod D be made long enough, and a sufficient degree of strength be employed, to raise it with the weight of the water above the bucket, without ever lengthening the stroke.

The force required to work a pump, will be as the height to which the water is raised, and as the square of the diameter of the pump-bore, in that part where the piston works. So that, if two pumps be of equal heights, and one of them be twice as wide in the bore as the other, the widest will raise four times as much water as the narrowest; and will therefore require four times as much strength to work it.

The wideness or narrowness of the pump, in any other part besides that in which the piston works, does not make the pump either more or less difficult to work; except what difference may arise from the friction of the water in the bore, which is always greater in a narrow bore than in a wide one, because of the great velocity of the water.

The pump-rod is never raised directly by such a handle as E at the top, but by means of a lever, whose longer arm (at the end of which the power is applied) generally exceeds the length of the shorter arm five or six times; and, by that means, gives five or six times as much advantage to the power. Upon these principles, it will be easy to find the dimensions of a pump that shall work with a given force, and draw water from any given depth.

The quantity of water raised by each stroke of the pump-handle, is just as much as fills that part of the bore in which the piston works, be the size of the rest of the bore above and below the piston what it will. The pressure of the atmosphere will raise the water 32 feet in a pipe exhausted of air; but it is advisable never to have the piston more than 20 or 24 feet above the level of the surface of the water in which the lower end of the pump is placed: and the power required to work the pump will be the same, whether the piston goes down to be on a level with the surface of the well, or whether it works 30 feet above that surface; because the weight of the column of air that the piston lifts, is equal to the weight or pressure of the column of water raised by the pressure of the air to the piston. And although the pressure of the air on the surface of the well will not raise or force up the water in the pump-bore more than 32 feet, yet when the piston goes down into the column so raised, the water gets above it, and may then be raised to any height whatever, above the piston, according to the quantity of power applied to the handle of the pump for that purpose.

Pumps ought to be made so (says Mr. Ferguson) as to work with equal ease in raising the water to any given height above the surface of the well. And this may be done by duly proportioning the diameter of the bore (in that part where the piston works) to the height the water is to be raised, as that the column of water may be no heavier in a long pump than a short one; or indeed equally heavy in all pumps from the shortest to the longest, on a supposition that the diameter of the bore is of the same size from top to bottom: and whatever the size of the bore be, above or below that part in which the piston works, the power required to work the pump will be just the same as if the bore was of the same size throughout.

In order that a man of common strength may raise water by pumps with the same ease, to any height not less than 10 feet, or more than 100 feet, above the surface of the well, Mr. Ferguson has calculated the annexed table, in which the diameter of the bore is duly proportioned to the height; and in these calculations he supposes the pump handle to be a lever increasing the power five times.

Height of the Pump, in Feet, above the Surface of the Well.	Diameter of the Bore.		Water discharged in a Minute, in Wine Measure.	
	Inches.	100 Parts of an Inch.	Gallons.	Pints.
10	6	.93	81	6
15	5	.66	54	4
20	4	.90	40	7
25	4	.38	32	6
30	4	.00	27	2
35	3	.70	23	3
40	3	.46	20	3
45	3	.27	18	1
50	3	.10	16	3
55	2	.95	14	7
60	2	.84	13	5
65	2	.72	12	4
70	2	.62	11	5
75	2	.53	10	7
80	2	.45	10	2
85	2	.38	9	5
90	2	.31	9	1
95	2	.25	8	5
100	2	.19	8	1

In the first column, look for the number of feet the water is to be raised; then, in the second column you have the diameter of that part of the bore in which the piston or bucket works; and in the third column, the quantity of water which a man of ordinary strength can raise in a minute by the pump to the given height.

The quantity of water contained in a pipe of either of those heights in the table, supposing the diameter of the bore to be the same from top to bottom of the pipe, is 4523.2 cubic inches, or 19.58 gallons in wine measure, as near as the hundredth part of an inch in the diameter of the bore can make it.

Mr. Ferguson has calculated the following table, by which the quantity and weight of water in a cylindrical bore of any given diameter and perpendicular height may be very readily found.

Diameter of the cylindrical Bore one Inch.			
Feet high.	Quantity of Water in cubic Inches.	Weight of Water in Troy Ounces.	In Avoirdupois Ounces.
1	9.4247781	4.9712340	5.4541539
2	18.8495562	9.9424680	10.9083078
3	28.2743343	14.9137020	16.3624617
4	37.6991124	19.8849360	21.8166156
5	47.1238905	24.8561700	27.2707695
6	56.5486686	29.8274040	32.7249234
7	65.9734467	34.7986380	38.1790773
8	75.3982248	39.7698720	43.6332312
9	84.8230029	44.7411060	49.0873851

For tens of feet high, remove the decimal points one place towards the right hand; for hundreds of feet, two places; for thousands, three places; and so on. Then multiply each sum by the square of the diameter of the given bore, and the products will be the answer.

Example.

Qu. *What is the quantity and weight of water in an upright pipe 85 feet high, and 10 inches in diameter of bore? The square of 10 is 100.*

Feet high.	Cubic Inches.	Troy Ounces.	Avoirdupois Ounces
80	753.982248	397.698720	436.332312
5	47.1238905	24.8561700	27.2707695
85	801.1061385	422.5548900	463.6030815
Multiply by	100	100	100
Ans.	80110.6138500	42255.4890000	46360.3081500

Which number (80110.61) of cubic inches being divided by 231, the number of cubic inches in a wine gallon, gives 342.6 for the number of gallons in the pipe: and 42255.489 troy ounces being divided by 12, gives 3521.29 for the weight of the water in troy pounds: and lastly, 46360.3 avoirdupois ounces being divided by 16, gives 2897.5 for the weight in avoirdupois pounds.

The power required to work a pump, or any other hydraulic engine, must not only be equal to the weight of the whole column of water in the pump bore, but as much superior to it as will overcome all the friction of the working parts of the engine.

PUMP, the Forcing, raises water through the box H (fig. 5.) not in the same manner as the sucking-pump does, when the plunger or piston *g* is lifted up by the rod *D d*. But this plunger or forcer (see **FORCER**) has no hole through it, to let the water in the barrel BC get above it, when it is depressed to B; and the valve *b* (which rose by the ascent of the water through the box H when the plunger *g* was drawn up) falls down and stops the hole in H, the moment that the plunger is raised to its greatest height. Therefore, as the water between the plunger *g* and box H can neither get through the plunger upon its descent, nor back again into the lower part of the pump L *e*, but has a free passage by the cavity around H into the pipe MM, which opens into the air-vessel KK at P; the water is forced through the pipe MM by the descent of the plunger, and driven into the air-vessel; and in running up through the pipe at P, it opens the valve *a*; which shuts at the moment the plunger begins to be raised, because the action of the water against the under side of the valve then ceases.

The water being thus forced into the air-vessel KK by repeated strokes of the plunger, gets above the lower end of the pipe GHI, and then begins to condense the air in the vessel KK. For as the pipe GH is fixed airtight into the vessel below F, and the air has no way to get out of the vessel but through the mouth of the pipe at I, and cannot get out when the mouth I is covered with water, and is more and more condensed as the water rises upon the pipe, the air then begins to act forcibly by its spring against the surface of the water at H: and this action drives the water up through the pipe FHGF, from whence it spouts in a jet S to a great height; and

is supplied by alternately raising and depressing of the plunger *g*, which constantly forces the water that it raises through the valve H, along the pipe MM, into the air-vessel KK.

The higher the surface of the water H is raised in the air-vessel, the less space will the air be condensed into, which before filled that vessel; and therefore the force of its spring will be so much the stronger upon the water, and will drive it with the greater force through the pipe at F: and as the spring of the air continues whilst the plunger *g* is rising, the stream or jet S will be uniform, as long as the action of the plunger continues: and when the valve *b* opens, to let the water follow the plunger upward, the valve *a* shuts, to hinder the water, which is forced into the air-vessel, from running back by the pipe MM into the barrel of the pump.

If there was no air-vessel to this engine, the pipe GHI would be joined to the pipe MMN at P; and then the jet S would stop every time the plunger is raised, and run only when the plunger is depressed.

Mr. Newsham's water engine, for extinguishing fire (see **FIRE-ENGINE**), consists of two forcing-pumps, which alternately drive water into a close vessel of air; and by forcing the water into that vessel, the air in it is thereby condensed, and compresses the water so strongly, that it rushes out with great impetuosity and force through a pipe that comes down into it; and makes a continued uniform stream by the condensation of the air upon its surface in the vessel.

By means of forcing-pumps, water may be raised to any height above the level of a river or spring; and machines may be contrived to work these pumps, either by a running stream, a fall of water, by horses, or by steam. See **WATER WORKS**.

The rod of the bucket in a sucking-pump is sometimes made to work through a collar of oiled leathers and brass plates connected with the barrel of the pump by screws, and kept moist by water contained in a vessel at the top: it prevents the water issuing from the top of the pump, and therefore, by a pipe, it will rise to any height. This is called in the North, a *jack-head*. Defaguliers's Exp. Phil. vol. ii. p. 152, &c. Ferguson's Lectures, p. 73, &c. 4to.

PUMP, the Lifting, differs from the sucking-pump only in the disposition of its valves, and the form of its piston frame. This kind of pump is represented in fig. 6. AB is a barrel fixed in a frame IKLM, which is immoveable, with its lower part communicating with the water. GEQHO is a frame with two strong iron rods, moveable through holes in the upper and lower parts of the pumps IK and LM; in the bottom of this frame OQH, is fixed an inverted piston BD, with its bucket and valve upon the top at D. Upon the top of the barrel there goes off a part FR, either fixed to the barrel, or moveable by a ball and socket; but in either case water and air-tight. In this part, at C, is fixed a valve opening upwards. It is evident, that when the piston frame is thrust down into the water, the piston D descends, and the water below will rush up through the valve D, and get above the piston; and that, when the frame is lifted up, the piston will force the water through the valve C up into the cistern P, there to run off by the spout. The piston of this pump plays below the surface of the water. Mr. Martin has described a mercurial pump, which works by quicksilver, invented by Mr. Hoskins, and perfected by Defaguliers; and another pump of the lifting sort, invented by Messrs. Goffet and De la Denille, and set up in the king of France's garden at Paris, the piston

of which works without friction. Phil. Brit. vol. ii. p. 57, &c. ed. 3.

PUMP, Ctesebes's, the first of all the kinds, acts both by suction and pulsion. Its structure and action are as follow:—A brass cylinder *ABCD* (fig. 7.), furnished with a valve in *L*, is placed in the water. 2. In this is fitted the embolus *MK*, made of green wood, which will not swell in the water, and adjusted to the aperture of the cylinder with a covering of leather, but without any valve. In *H* is fitted on another tube *NH*, with a valve that opens upwards in *I*.

Now, the embolus *EK* being raised, the water opens the valve in *L*, and rises into the cavity of the cylinder: and when the same embolus is again depressed, the valve *I* is opened, and the water driven up through the tube *HN*.

This is the pump used among the ancients, and that from which both the others are deduced. Sir S. Morland has endeavoured to increase its force by lessening the friction; which he has done to good effect, inasmuch as to make it work without almost any friction at all.

PUMPS for draining Mines are worked by horses, or water, but more than either by the steam-engine, which, had it produced no other advantage than the facilities it offers in mining, would have been of more real value than any philosophical discovery ever made. The pumps for this purpose are generally sucking-pumps of the common construction, made of cast-iron, except that they have an opening at the lower part of the barrel, to give access to the valve or bucket when they require repair or renewal of the leathers, and this is closed by a door or lid, fastened on with screws. The pump rod is suspended by chains from the arched end of a lever situated over the pit, and put in motion by the piston of the steam-engine acting at the opposite end, or by a crank turned from a horse-wheel or water-wheel. When the depth is considerable, the pit is divided into two or three lifts, and as many different pumps used; the lowest to raise the water from the bottom of the mine into a cistern at the first lift, in which the second pump stands, and raises the water to a second cistern, from which the third or upper pump raises it to the surface, or to the level or subterranean passage, at which it can run off to some lower land than that on which the engine is erected. The rods of the three pumps are brought into one by bolting them together at the top, and are suspended from the beam or lever, as before-mentioned. They are made of wood, the lengths being united together by iron joints; but even these in deep mines are of such great weight as to require a second beam or lever, placed on the opposite side of the pit to the engine, and having a balance weight at the outer end; because it would be too great a weight for any beam to bear, if a sufficient balance were put upon the opposite end of the same working beam that bears the strain of working the pumps: if they are of light wood, a considerable portion of their weight is taken off, by their being immersed in the water which the pumps contain.

A plan which is common in the mines of Cornwall, obviates the necessity of thus balancing the pump rods; it is by employing forcing-pumps instead of lift or suction-pumps. In these the engine is employed to lift the weight of the rods, and their descent is the power that raises the water in the pump, by pressing down the piston or forcer, and expelling the water from the barrel at the bottom through a valve into a pipe, which ascends the pit. The construction of the pump is varied from that in common use, though its principle is the same. Instead of the barrel

being bored correctly within, and fitted with the leathered forcer, the forcer is made rather longer than the stroke of the pump, and being made true and smooth on the outside, it is fitted in a collar of leather at the top of the barrel of the pump. By this means, when the piston is raised up and down, it increases and diminishes the capacity of the barrel, which being provided with valves at the bottom and at the foot of the pipe, it will raise or force up the water, in the same manner as the force-pump before described.

The suction-pumps before mentioned, used in mining, are always made of cast-iron, in lengths of six or eight feet, screwed together at the flanches, forming a long tube, which is called the pile or pillar of pumps.

The working barrel of each lift of pumps, or that length of pipe in which the bucket moves, is usually fourteen to twenty feet above the bottom, and has at its upper end a wider part, and a cover, which, like that above-mentioned, takes off by screws to new leather, or to repair the bucket. The bottom length of mine-pumps is called the wind-bore, usually enlarged at two or three feet from the bottom, and diminishing thence to a point like that of an egg, which part is full of rows of holes three quarters or an inch in diameter. The upper row of these holes is plugged up with deal plugs, which the miners can open or stop as the water increases, or otherwise, and according to the going of the engine. When a pit or mine is first sinking, it becomes necessary to contrive the means of drawing the water completely from the bottom, that they may not have to stand in the water to work, which, besides its inconvenience, prevents them using gunpowder if the bottom is rocky. Sometimes, instead of the plugs of wood, the holes of the wind-bore are surrounded by a circular apron of strong leather, made fast and tight above to the pipe; which apron the miners can from time to time turn up or down like the cuff of a coat, so as to regulate the access of water, and prevent, as much as possible, the drawing of air by the pumps, as this deranges the motion of the engine. In sinking pits, the lower lift of pumps should stand in the deepest hole which has been made in the bottom of the pit, and for this purpose, when a new hole has been made, either by picking, or blasting, near to the pumps, they are levered towards, and let to sink into such new hole. In long lifts and heavy pumps, this lowest and moveable length of the pump is wholly or in part suspended by strong ropes attached to the great windlass, which is, in all such cases, provided near the shaft for drawing the pump rods, or the pumps themselves, in cases of need. As the shaft is deepened, new lengths of pump barrels are added at the top of the lower lift, generally about a yard at a time, and the pump rods are lengthened as the pump requires. This, which is the common mode of working in sinking pits, has many inconveniences: 1. As it is necessary for the pumps, whilst sinking, to keep the water very low in the pit, the engine frequently goes too fast, in consequence of the pump drawing up air, and carries up by the violence of the current small pieces of stone, coal, or other substances, and lodges them above the bucket upon the valves, which must considerably retard the working of the pump, and wear the leather. 2. When the engine is set to work, (after having been stopped whilst working upon air, and consequently a quantity of air remaining in the pump-barrel, with the small stones, &c. deposited on the valves of the bucket,) it often happens that the compressure of the air by the descent of the bucket, is not sufficient to overcome the weight of the bucket valves so loaded with rubbish, and the column of water in the stand-pipes: the pump is hereby prevented from

catching its water. The usual remedy for this is to draw the bucket out of the working barrel, until a quantity of water has escaped by its sides to displace the air: this evil often arises from the unnecessary magnitude of the space between the bucket and clack. 3. The pumps being suspended in the pit by capstan ropes for the purpose of being readily lowered as the pit is sunk, the stretching of the ropes, (especially when sinking in soft strata,) occasions much trouble, by suffering the pumps to rest on the bottom and choke; but the most serious evil is, that the miners, in shifting the pump from one place to another, that they may dig in all parts of the pit, throw them very far out of the perpendicular, thereby causing immense friction and wearing in all parts, besides endangering the whole apparatus, by breaking the bolts and stays, and straining the joints of the pipes.

Mr. William Brunton, of Butterly iron-works in Derbyshire, has presented to the Society of Arts an improved pump for mining, which obviates all the above difficulties. To avoid the pump drawing air, he has introduced a side pipe, connecting the parts of the working barrel which are above and below the bucket, which pipe has a stop-valve, that the miner can regulate with the greatest ease, so as to keep the engine to its full stroke, without drawing air, by letting down the water from the upper part of the barrel into the lower, so that it is working again in its own water. Instead of having the whole weight of the lower lift of pumps standing on the bottom, it is fixed in the pit by cross beams, and the miner has only to lift and move an additional pipe or wind-bore, which slides upon the lower length of the pump like a telescope, to lengthen down, and this additional wind-bore is besides crooked, and turned aside like a short crank, which, by the facility with which it turns round in the leathered collar above the nose of it, can easily be removed into every fresh hole which is made in the bottom by the miners. The pumps are supported in the pit by beams placed across at proper distances, so as to suit the lengths of the pipes, or lengths of the pump, which are nine feet. Short pieces are laid across these, with half circular holes in them, which being put round the pump, just beneath the flanches, firmly sustain its weight, but may quickly be removed when it is required to lower the pumps in the pit; and as they are not fastened by any bolt, they do not prevent the pumps being drawn upwards, if it becomes necessary to take out the pumps when the pit is full of water. The pumps by these means remain stationary and the suction-pipe lengthens as the pit is sunk, until it is drawn out to its full extent; the whole column is then lowered to the next flanches, and another pipe is added to the top. The pumps being thus kept stationary till nine feet are sunk, the pipe at the top will of course deliver the water at the same level at all times, and instead of being obliged to lengthen the column every yard sunk, it will only be necessary every nine feet. *Fig. 4. of Plate XV. Hydraulics*, explains the construction of Mr. Brunton's pump, being a section through the centre of the working barrel and suction piece. A is the door which unscrews to get at the clack of the pump; B is the working barrel, with the bucket D working in it; E is the clack, also shewn enlarged in *figs. 5 and 6*; F is the suction-pipe, and G G a moveable lengthening piece: this slides over, and includes the other when the pump is first fixed; but as the pit is sunk, it slides down over the pipe F, to reach the bottom. The outside of the inner pipe, F, is turned truly cylindrical and smooth, and the inside of the outer pipe G, at the upper end, for about six inches down, is made to fit it. The junction is made perfect, by leathers being placed in the bottom of the cup *a a*, which holds water and wet clay over

them, to keep them wet and pliable, and consequently air-tight. The lower extremity of the suction-pipe G terminates in a nose R, pierced with a number of small holes, that it may not take up dirt. This nose is not placed in a line with the pipe, but curved to one side of it, like a crank, so as to describe a circle when turned round. By this means the miners, by turning it round upon the pipe F, can always place the nose R in the deepest part of the pit; and when they dig or blast a deeper part, they turn the nose about into it, the sliding tube lengthening down to reach the bottom of the hole, as shewn in the figure. By this means there is never a necessity to set a shot for blasting, so near the pump-foot as to put it in any danger of being injured by the explosion, as is the case in the common pump, in which this danger can only be avoided by moving the pump-foot to one side of the pit, which necessarily throws the whole column of pumps out of the perpendicular.

The construction of the clack is explained by *figs. 5 and 6*, the former being a section, and the latter a plan. L L is a cast-iron ring, fitting into a conical seat in the bottom of the chamber of the pump, as shewn in *fig. 4*; it has two stems, *l, l*, rising from it, to support a second iron ring M M; just beneath this, a bar, *m*, extends across from one stem to another, and has two screws tapped through it; these press down a second cross-bar *n*, which holds the leather of the valves down upon the cross-bar of the ring L, and this makes it fast, forming the hinge on which the double valves open, without the necessity of making any holes through the leather, as is common: but the chief advantage is, that by this means the clack can be repaired, and a new leather put in, with far less loss of time than at present, an object of the greatest importance; for in many situations the water gathers so fast in the pit, that if the clack fails, and cannot be quickly repaired, the water rises above the clack door, so as to prevent any access to it, and there is no remedy in the common pump but drawing up the whole pile of pumps, which is a most tedious and expensive operation. In Mr. Brunton's pump, the clack can at any time be drawn out of it, by first drawing out the bucket, and letting down an iron prong Z, which has hooks on the outside of its two points: this, when dropped down, will fall into the ring M, and its prongs springing out will catch the under side, and hold it fast enough to draw it up. Another part of Mr. Brunton's improvement consists in the addition of a pipe H, (*fig. 4*.) which is cast at the same time with the barrel, and communicates with it at the top and bottom, just above the clack: at the upper end the pipe is covered by a flat sliding plate, which can be moved by a small rod *b*, passing through a collar of leather; the rod has a communication by a lever, so that the valve can be opened or shut by the men in the bottom of the pit. The object of this side pipe is to let down such a proportion of the water which the pump draws, as will prevent it drawing air, though, of course, the motion of the engine will be so adapted as not to require a great proportion of the water to be thus returned through the side pipe, yet it will not be possible to work the engine so correctly as not to draw some without this contrivance, and if it does, it draws up much dirt and pieces of stone into the pump, besides causing the engine to work very irregular, in consequence of partially losing its load every time the air enters the pump. Another use of the side pipe is to let down water into the chamber of the clack to fill it, when the engine is first set to work, after the pumps have been standing still, and the lower part of the barrel and chamber empty.

Figs. 7 and 8, of Plate XV. are a section and elevation of a three-barrelled force-pump, of a very good

construction, which was used by Mr. Smeaton in the numerous water-engines which he erected at London bridge, Stratford, and other places for the supply of towns with water. It has the advantage of the valves being very accessible, and the water-way may be kept to the full size of the barrel without contractions, which, as they occasion great resistance to the motion of the water, are a waste of power. It acts on the same principle as the ordinary forcing-pump, only that three barrels are connected together, for the advantage of raising a constant stream of water. *A, A*, are the barrels, which are bored out truly cylindrical. If the pump is small, the barrels are usually made of brass, but for larger work cast iron is used. From one side, near the bottom of each, proceeds a curved pipe *B*, turning up, and ending with a flaunch, to screw to the under side of the forcing chamber *L*. There is also, near the bottom, at the opposite side of the barrel, a projecting neck or short pipe, *D*, covered at the end by a door screwed on, that it may be removed to give access to the valve, *m*, in the bottom of the barrel. The barrels have projecting rings or flanches, by which they are screwed down upon the suction chamber *II*, which is common to all three barrels; it has a pipe from each of its ends terminating in a flaunch *b*, to screw on the pipes which bring water to the pump. The upper flaunch, or top of the suction chamber *II*, has three holes in it, one under each barrel, and each is covered by a valve shutting downwards, as is shewn in the section, *fig. 7*. These valves are made of iron, to shut down upon hinges like a door, and are covered with leather at the lower side. Mr. Smeaton made his valves with the centre pin of the hinge removed backwards from the hole which the valve covers, and it is also raised above the surface of the under side of the valve, by which means the valve opens in some degree on that side where the hinge is, as well as on the other, and any obstruction getting into the valve, will be less liable to be detained, and will not have such a great leverage to break the hinge of the valve when the force of the water shuts it down, as it would if the hinge was on a level, and close to the edge of the hole, because the obstacle will not be so near the centre. The hinge is fastened to the pump by a screw, *cc*, passing through the metal, and screwing into the hinge; this being withdrawn, and the door, *D*, opened, the valve is quite loose, and may be taken out to renew the leather. To give facility to this, the doors, *D*, are made oval, as shewn in *fig. 8*. Another similar valve, *n*, is fitted at the top of each of the pipes, *B*, to cover their apertures; they are all covered by a common forcing chamber, *L*, which is exactly similar to the suction chamber, except that it has nozzles, *R*, in the top over each valve, and covered with doors to give access to them. The conducting pipes are carried away from either end of the forcing chamber, flanches being provided to unite them. Each barrel is fitted with a piston or forcer *M*, which consists of three metallic plates, secured to the rod: the middle plate is turned true, and fitted as accurately as possible to the barrel; the upper and lower plates are somewhat smaller. Two round pieces of leather, larger than the barrel, are placed above and below the middle plate, being held fast between it and the upper and lower plates. When forced into the barrels, these leathers turn up and down round the upper and lower plates, forming two cups of leather, which accurately fit the barrel, and will not permit any fluid to pass by them. The parts of the pump are fastened together by screws and nuts, as will be understood by inspection of the figures. The whole pump is supported on two ground-cills, and by means of two iron flanches of the suction chamber, *H*, the whole pump is bolted down upon the ground-cills. The action of this pump is simply

this; when the piston or forcer of one barrel is raised, it causes a vacuum in it, and the pressure of the atmosphere forces the water up the suction pipe *H*, (if not more than 30 or 33 feet,) opens the valve, *m*, in the bottom of the barrel, and fills it with water: on the descent of the forcer the lower valve shuts, and the forcing valve, *n*, opens by the water the barrel contained being driven through it into the forcing chamber, *L*, and thence to any place whither the forcing-pipe is carried. On the re-ascent of the forcer, the lower valve, *m*, opens, and the shutting of the forcing valve, *n*, prevents the water returning into the barrel. The three forcers work up and down alternately, so that while one barrel is sending water up the force pipe, the others are lifting it up the suction pipe, and the third continues the action in the interval, when the change of motion takes place between the two. In this manner, the pump will raise a very constant stream of water, if the forcers are worked in a proper manner, which is best done by means of cranks, placed at such an angle to each other, upon the same axis, that they will act in due succession.

Pumps for Ships.—Among the perils of a sea-faring life, a leaking ship may be reckoned the most dreadful and fatal of all others: here not only one man, or a few men, perish, but every living creature on board. When a ship strikes against a rock, and is wrecked, some lives may be saved by floating planks and rigging; if the magazine takes fire, death comes instantaneously, and kills, perhaps, in the most gentle manner; but in the desperate case of a leak, how slowly does the awful monarch advance, attended by all the terrors of anxious suspense.

In such a melancholy situation, all their hopes and expectations for help and safety must be placed in the pumps, and this consideration renders those machines of vast estimation and consequence; it highly imports every commander of a ship (to whom the lives of his men are committed) to take the utmost care that his ship be supplied with such pumps as will best provide against, and ward off, these impending dangers. By any negligence in this respect, he may become guilty of destroying his own life, the lives of his men, and of the ruin and misery of many families; it therefore becomes his duty to be furnished with the best pump that can be procured for evacuating the hold from the water that may, at any time, get in, with the least force, and in the shortest time.

At different times, almost every description of pump has been employed in ship service; but custom has at length decided in favour of the chain-pump, although, from the friction naturally attending its construction, it takes somewhat more power to raise a certain quantity of water than some other kind of pump when well made. Yet on the whole, from being so little liable to choke up or be deranged by violent use, it has gained the preference with the seamen. Constant attempts have been made to produce a pump that would raise a greater quantity of water than the chain-pump with the same power, and still to preserve the other advantages of that machine.

These inventions have been offered to the public one after another, with pompous recommendations by their respective projectors, who have never failed to report their effects as considerably superior to that of other pumps with which they have been tried. It is, however, much to be regretted, that in these sorts of trials there is not always a scrupulous attention to what may be called mechanical justice. The artist who wishes to introduce a new piece of mechanism, has generally sufficient address to compare its effects with one of the former machines which is crazy, or out of repair: a report of this kind, indeed, favours strongly

of the evidence of a false witness; but this finess is not always discovered. The persons appointed to superintend the comparative effect of the different pumps, have not always a competent knowledge of hydraulics to detect these artifices, or to remark, with precision, the defects and advantages of those machines, as opposed to each other. Thus, the several inventions proposed to supplant the chain-pumps which are now generally used in the British navy, have hitherto proved ineffectual, and are no longer remembered.

In many instances, for want of a proper knowledge of mechanics and hydraulics, these inventions have proceeded upon a mistaken principle, supposing it possible to make some contrivance or other, by which a pump should raise more water with a certain power than has ever been done before. This is a mistaken idea, for pumps, in point of the quantity of water they will raise, have long ago been brought to as great a degree of perfection as it is perhaps possible; and to raise a greater weight of water than the power applied is equal to, is an impossibility, as no power or effort can really be increased by any kind of machinery, it can only be modified; and what is gained in the magnitude of the effect the machine produces, is lost in the time expended to accomplish it: in truth, rather more is lost, because of the friction of the machine, and the power expended in working its parts; we should, therefore, ascertain the quantity of water that can be raised in a given time by the force of one or more men, without deductions for friction; and when a ship's, or other pump is to be considered, if its produce comes near to this standard, we should be satisfied as to its performance, and look for improvements in the convenience of its construction.

Defaguliers, in the second volume of his *Experimental Philosophy*, has taken much pains to find out an average of the quantity of water which can be raised in a given time by any number of men; and this will serve to guide us in these pursuits, and to enable us to value the pretensions of projectors in the art of raising water. He found, that the mean strength of a man, when applied to the best kind of pump that had been in his time made, amounts to no more than the raising of one hoghead of water in a minute, to the height of ten feet. Mr. Smeaton says, he made a variety of machines, and many observations of this kind, but never found the value of men's strength at a medium quite equal to what is set down by Defaguliers, unless they are supposed to work in haste or distress for a few minutes.

The improvements which are desirable in pumps for a ship's use, are, 1st, that as little power as possible should be lost in friction and resistance of the water passing through the valves and pipes; 2^{dly}, that no water be lost by leakage, and that the pump be not liable to choke up by chips or other extraneous matters getting into the pump; 3^{dly}, it should not be obliged to raise its water to a greater height than is necessary for it to run off, namely, to the load-water line of a ship; lastly, that it should be so adapted, that the united efforts of a great number of men can be applied, without any of them working to a disadvantage. The pumps which are at present in use in the navy are of two kinds, the chain-pump, and the hand-pump; the chief dependence of pumping the ship, in emergency, being placed upon the former, the latter being used on ordinary occasions, to clear the hold from that trifling leakage which would injure the cargo, though it puts the ship in no danger.

English ships of war carry four chain-pumps and three hand-pumps, all being fixed in the same well, which also includes the main-mast. (See *Plates IV. and VI. of Naval*

Architecture.) One of the hand-pumps is called the wash-deck pump, being used to raise water from a cistern in the hold to the upper deck, for washing the ship; but in emergency, it assists to pump the ship. The chain-pump (*Plate XIV. fig. 8.*) is no other than a long chain, *A*, with a sufficient number of pistons, *a*, called buckets or saucers, fixed upon it at proper distances: it passes downwards through a wooden tube, *B*, and returns upwards, in the same manner, on the other side, *D*; the ends being united together. The chain is extended over two wheels, *E* and *F*, called sprocket wheels; one is placed over the tubes, *B* and *D*, of the pump, and the other at the bottom, in the space between the two tubes through which the chain ascends and descends. By turning the upper wheel, *E*, the chain of buckets is put in motion; and the lower part of the wooden tube, in which the chain ascends, is lined with a brass barrel, in which the saucers are fitted. As they are continually ascending in this tube, they raise a constant stream of water, which runs off from the top of the ascending trunk, and is carried by a trunk through the ship's side into the sea. The pump is worked by a crank, or winch, *G*, fixed on the axis of the upper wheel, whereon several men may be employed at once; and thus it discharges, in a limited time, a much greater quantity of water than the common pump, and that with less inconvenience to the labourers.

The chain-pump now in use in the navy is of a very improved construction, compared with original chain-pumps. It was introduced by Mr. Cok, under the direction of captain Bentinck. The chain of this machine is simple, and not much exposed to damage. It is exactly similar to that of the fire-engine, and appears to have been first applied to the pump by Mr. Mylne, to exhaust the water from the caissons at Blackfriars bridge. It has thence been transferred to the marine by captain Bentinck, after having received some material additions to answer that service. The links of the chain (*fig. 9.*) are each formed of two long plates of iron, *e, e*, with a hole at each end, and fixed together by two bolts, serving as pins for the joints. The buckets or saucers fixed upon it are two circular plates of brass, *g*, with a piece of leather between them. The sprocket wheels for the chain are formed in the same manner as the trundles used in mills, by two iron wheels fixed at eight inches distance upon the axle, and united by several round iron bolts, forming a rest for the chain; and its links have hooks, *h*, which are taken by these bolts; and thus the chain is secured upon the wheel, to prevent it from jerking back, when charged with a column of water.

This pump was a great improvement upon the old chain-pump used in ships before which the chain was of too complicated a fabric, and the sprocket wheels used to work it were deficient, in wanting some contrivance to prevent the chain from sliding or jerking back upon the surface of the wheel, which frequently happened when the buckets were charged with a considerable weight of water, or when the pumps were violently worked. The links were too short, and the awkward manner in which they were connected exposed them to a great friction in passing round the wheel: hence they were sometimes apt to break, or burst asunder, in very dangerous situations, when it was extremely difficult or impracticable to repair the chain. Mr. Cok's pump is so constructed, that the chain may be easily taken up and repaired, when broken, or choked with ballast; and it discharges a much greater quantity of water with an inferior number of men, as appears from a trial of this machine with the old chain-pump aboard the *Seaford* frigate; where it was found that its effects, when compared with the latter, were as follows: the new pump with four

men raised one ton of water in $43\frac{1}{2}$ seconds, while the old pump required seven men to raise the same quantity of water in 76 seconds. In this experiment, the chain of the new pump was purposely broken, and dropped into the well, and afterwards taken up and repaired, and set to work again in two minutes and a half: then the lower wheel of the pump was taken up, to shew how readily it might be cleared and refitted for action, after being choked with sand or gravel, which could be performed in four or five minutes. These are advantages which, with a seaman, have a superior consideration to that of increasing the quantity of water which the machine will raise, unless it was in a considerable degree; and indeed the very best pumps will not raise a much greater proportion with the same power. The only alteration which has been made on Mr. Cole's pump, since its first introduction near 30 years ago, is that they now omit the lower sprocket wheel altogether, the ascending and descending pipes being so united by a curved metal tube, that the chain passes better than if a wheel was used. The cranks are made to take off, and apply when wanted, that they may not be in the way: they are long enough for 30 men to work at once. Of late it has been proposed to add fly-wheels to them: this would be attended with but slight advantage, and several inconveniences, from occupying that room where the men should stand to work, it being an object to employ as many as possible; but if they are crowded, they only incommode each other, instead of assisting.

Hand-pumps for ships, are those which act with a barrel and bucket, worked by a lever or brake. Those in common use are sucking-pumps, made in the rudest manner, with a wooden bucket and valves; but several improved constructions have been proposed, and are now adopted in the navy. Mr. Cole made great numbers of hand-pumps, which had brass chambers, or barrels, fitted into the wood where the bucket worked. The valves were made of brass, and fitted into a conical seat, and a door was provided in the lower part of the pump, to give access to the lower valve when requisite; it was closed by a hoop surrounding the pump, and wedged tight. The brake, or lever of the pump, had a cross handle at the end, of sufficient length to allow several men to work together, and on occasion other men could apply their strength, by standing on the deck below, and having a rope descending through the upper deck from the end of the brake.

Mr. Smeaton, in 1765, invented a hand-pump for the sea service, in which, besides the advantage that he expected to obtain from better mechanism and proportion of the parts, he had the following objects in view. The common ship's pump, in general, delivers its water upon the main deck, which, according to the size and construction of the ship, is four, five, or six feet above the surface of the sea, or load-water line, at the same time that this line is not above from 14 to 18 feet above the ship's bottom; it therefore appears that the ordinary pumps lift the water from $\frac{1}{3}$ to $\frac{1}{4}$ th higher than the level at which the water might be delivered, and thereby require $\frac{1}{3}$ or $\frac{1}{4}$ th more power to do the same work, or with the same power they do less work than they might do by $\frac{1}{3}$ or $\frac{1}{4}$ th, in case the water was delivered at or just above the water line. For this purpose he used wooden trunks or pipes, proceeding horizontally from the upright trunk of the pump, to carry off the water through the ship's side, being fitted at the other ends into boxes, or short wooden tubes, let in through the ship's side, and caulked just above the load-water line. These side pipes were closely jointed with the boxes in the ship's side at one end, and at the other end into strong planks, which were bolted against the

sides of the pump, in order that the side pipes might be got out and in without disturbing the pump, which was a sucking-pump, with its bucket worked by a lever or brake, upon the deck over the pump. From the top of the pump, a stand pipe was carried up to the main deck, or as high as was thought necessary, to prevent the water reverting and running back into the ship over the top of the pump, when the sea rose above the orifices of the side pipe, or when, from the ship being in distress, they were under her load-water line. By this, even when both boxes and pipes were wholly under water, it would no ways interrupt the action of the pump, for whenever the water in the stand pipe rose above the level of the water without, the pressure of the column in the stand pipe would cause it to make its way through the side pipes, so that in this case no level was lost, and though the pump was at rest no water could revert down the pump, because there were the valves of both bucket and fixed box or clack which prevented it. The working barrel was of brass, and very truly bored, the bucket and fixed box being of the same construction as those used in the steam-engines, and the pump rod was made of greater bulk than was necessary, merely for strength, but by way of weight, that when the brake was lifted up, the pump rod should readily descend by its own weight. The brake of the pump had a branch fixed on, rather obliquely at each side, so as to form three handles, for four men to work at once; they stood one on each side the middle stem of the brake, and one on the outside of each of the branches, and every quarter of an hour they could relieve themselves by changing hands, which was done by changing places. They were intended to make no more than 25 strokes per minute, moving the pump rod 17 inches, up and down, at each stroke, the barrel being a nine-inch bore; this was much better than making shorter strokes, and quicker, as they usually do. Their hands moved up, and down about four feet six inches, and by working with this stroke at a moderate rate, so as to hold it an hour, four men would in that time deliver 20 tons at a height of 22 feet. This was upon a supposition of raising the water to the usual height, but when by the application of the maxim before described, this perpendicular was shortened to 16 or 17 feet, then nearly the same delivery could be made by three men, or proportionably more by four men, that is, as 17:22::20:26 tons at 17 feet. The foot of the pump was let through the ship's main planking or ceiling, betwixt two of the floor timbers, and did not touch the bottom or outside planking, within $2\frac{1}{2}$ inches, the lower end being rounded within like a trumpet mouth, it being a bad plan to have the pump standing upon its lower extremity, with holes bored to let in the water, as it is thus very liable to be choked by dirt. A plank of the ceiling was made to lift up near the pump's foot, that a man could occasionally get in his arm, to clear away any chips, sand, dirt, or other matter, that should happen to be drawn thither.

Mr. Noble has furnished a great number of hand-pumps for the navy, which have two buckets, working one below the other in the same barrel: they rise and fall alternately, so as to produce a constant stream, like the chain-pump. This is effected by causing the rod for the lower of the two buckets to pass down through the upper bucket in a collar of leathers: the rods of the two buckets are united to the brake or lever, upon opposite sides of its centre or fulcrum, so that the descent of one produces the elevation of the other; thus one is always raising a stream of water, whilst the other is descending for a fresh supply. Such a pump requires no lower valve, unless by way of precaution, in case either bucket should fail, in which case it would become a single pump. The idea is ingenious; but the

complication of the stuffing-box in the upper bucket prevents them being readily taken out, if the pump chokes up, as all ships' pumps are liable to do from chips or loose ballast; and hence it has never been in favour with the seamen, although it acts very well when in order.

The ingenious Benjamin Martin invented a ship's pump with two barrels drawing from one suction-pump, so as to raise a constant stream. This has so much merit, that we have given a section of it in *Plate XV. fig. 9.* Here A is the suction pipe, conducting the water from the ship's hold up to the pump, where it is enlarged, to communicate with both barrels D, D, through the valves C, C, in the bottom; E, E, are the pistons of the barrels, with double valves in them; they are not, like other pistons, fitted to slide in the barrels, but are simply brass rings, in which the valves are fitted, and being smaller than the barrels, have large circular pieces of leather fixed on them, the outside edges of which are attached to the insides of the pump barrels; hence when the pistons are moved up and down, the leather folds sufficiently to admit the motion, as is shewn in the figure; but being close all round, these pistons can have no leakage or friction, and only a small resistance from the stiffness of the leather. To fasten the edges of the leather piston to the barrels, they are made in two lengths, an upper and a lower, and the leather is introduced in the joint between them, being held fast, and the pump kept together by bars, I, I, fixed over the barrels, and bolts to press the upper length of the barrels down upon the lower. Both the barrels are included within a box or cistern, B B, fixed upon the ship's deck, with trunks L, L, which carry off the water as it runs over the tops of the barrels into the cistern. The pump is worked by the piston-rods, H, H, being united by chains to a wheel K, the axle of which is supported by standards from the sides of the cistern B B, and is put in motion by the double lever M, at the ends of which cross handles are fixed for several men to work at once. Mr. Martin's pump acts extremely well; the constant stream raised by the alternate action of the two barrels upon one pipe produces an advantage that was shewn by experiment, for the water not only rises while the piston rises, but continues to do so even after the piston begins to descend; and therefore the pump was found to deliver more water than was expected from calculation of the contents of the barrel and the number of strokes made.

To account for this, it must be considered that as this pump has both its large pistons working (alternately ascending and descending), at the same time there must be produced a constant rising column of water in the pipe, whose velocity through a bore of five inches, to supply the barrels of twelve inches diameter each, must be so great, that it cannot be checked or stopped at once, or upon the first descent of the piston; and therefore a surplus of water is produced. Notwithstanding these advantages of Mr. Martin's pump, it has objections which are serious obstacles to its use on board ships, though in other situations it is a good machine: these are the shortness of its stroke, which renders it very fatiguing for men to work for a long time; but another more serious objection is, that the leathers would, in general, remain dry, and thus become liable to harden and grow stiff, so as to break into holes when used at first, before they become soaked, and to fill the cistern first with water would be very troublesome.

Mr. Robert Clarke, of Sunderland, has proposed an improvement in the mode of applying men's force to pumping, which is worthy the consideration of seamen. It is to change the posture of standing to sitting, and making the action the

same as that of rowing, which, besides that it is by philosophers considered as the most efficacious application of a man's force, is to seamen most particularly so from their habitual practice of it. He objects to the ordinary action of pumping with a brake, as the posture is weak, and requires much force to preserve it. It oppresses the man by overstretching his loins on one side, and incommodes respiration, by the flexure of the body on the other side. Too much motion of the shoulder-joint is required, as the muscles which act on the arm-bone at this joint are disproportionate to the effort they must make, when the arm vibrates on the shoulder-joint as a centre, for the force to be communicated by the hand. Besides this, the arms themselves are at one instant enfeebled, by being thrown above the head, and requiring a pull, and the next instant require a pushing effort, which changes of direction in the exertion and sustaining force, are too continual and rapid for long continuance; in standing, the body is a continued dead weight upon the legs.

The action of rowing is powerful to a surprising degree, and so well adapted to a man's case, that he can continue it a greater length of time without fatigue, than any other mode of exertion; for though the motion is large, it is made up of easy motions in several joints; the velocity and resistance of which suit the muscles employed. Very little sustaining force is required, for the body is supported, and returns unloaded to its charge: the breathing is free. The manner of carrying this into effect is very simple, the lever or brake being bent at right angles at a centre pin, so that it hangs straight down when it is at rest, instead of being horizontal; then to the lower extremity a rod is jointed, which is carried rather in an inclined direction upwards to the seaman, who is seated before the pump with a rest for his feet. The rod has a cross handle, to hold by both hands, and in some cases it may be made long enough for two men to sit side by side upon the same seat; and by drawing and pushing it, in the same manner as rowing, the perpendicular lever is caused to vibrate, and the horizontal arm, or bended part, which supports the pump spear, partakes of the motion sufficiently for pumping.

The latest improvements in hand-pumps, are by Capt. Jekyll, R. N. This gentleman has invented an addition to the pump of an air-vessel, and stuffing-box for the rod to pass through, by which it will raise the water to a greater height than the head of the pump, and a hose being attached to the pump spout, by very simple means, the water is conveyed to any desired part of the ship, and thrown in a jet through a nose pipe with great force, to extinguish fire, if such a calamity should befall a ship, and thus the pump is rendered of twofold service. The idea of converting the pump to a fire-engine is not new, having been attempted in many different ways by forcing-pumps, but these having pipes proceeding from the lower part of the barrels and valves, which are not very accessible, are always liable to choke up by obstructions, and have not succeeded in general use. The air-vessel has always been in the way, if made of a sufficient size, to answer the purpose of equalling the stream. Capt. Jekyll has obviated these objections, and, without altering the material parts of the hand-pump, has rendered it as complete a fire-engine as can be wished. This is explained by *fig. 1. Plate XV.* which is a section of the pump through its whole length. A B C is the iron brake or lever to work it; it is branched at the extreme end, and has a wooden pole, C, fixed in it, for several men to hold at once; D is the iron staunchion or fulcrum of the brake; it is fixed to the pump head by means of strong iron hoops at E E and F F, which at the same time strengthen the work of the pump. The centre pin is to be at a height of two

feet six inches above the ship's deck. H are the slings of the pump, united by a forelock or pin to the end of the brake, and suspending the pump-spear I, by means of the joint-piece g. I K is the pump-spear, made of copper in the upper part, I, and the lower length, K, of iron; the latter has the bucket, M, attached to it. The valve of the bucket is made in a very simple and effective manner, the valve being merely a round plate of brads, with a hole through the centre, to receive the rod, upon which it rises and falls, and covers the aperture in the bucket. The bucket is a ring of brads, with a cross-bar to fix the rod in; it is made in two thickneses, one above the other, and a cup of leather is held in between them, projecting all round the upper part of the bucket, and turning up, to make a tight fitting in the barrel. The two rings of the bucket are held together by the piston-rod passing through both, and a cross-wedge beneath. L is the brads chamber in which the bucket works; it is well fitted into the wood of the pump-tree, so that the water cannot leak by it, and is bored smooth withinside. N is the lower box, fitted into the lower part of the pump-tree, beneath the chamber; it has a groove round it, into which oakum is placed, and when it is put down, makes a tight joint: its valve is of the same construction as that of the bucket, with the addition of a ring or eye on the top of the pin, on which the valve rises and falls. By this eye the box can be drawn up when it needs repair, by first drawing up the bucket of the pump, and putting an iron hook down into this eye. O O P is the air-vessel; this is a cylinder of sheet copper, foldered to a cover of brads; within the centre of it is a tube, likewise foldered to the cover, through which the copper pump-spear passes, and is fitted round at top with a collar of leather and stuffing. To prevent the escape of the water, it is packed with hemp, and two rings of leather. R shews the place of two iron bars, fitted through the head of the pump, and confining the cover, O O, of the air-vessel; they are fastened by the wedges d: it is by these only that the air-vessel is held down: a circle of leather is first put round the air-vessel, just beneath its lid, and this being pressed upon the recess in the wood, makes the joint tight. T is the pump nozzle, which delivers the water. When it is used as a fire-engine, a hose is fixed on by its link-joints, and keys or wedges: the nozzle is fixed to the pump by four screw-bolts going through the thickness of the pump, and it is fixed in such a direction as will most conveniently lead to a receiver, *fig. 2*, which unites the hoses from all three of the ship's pumps.

Fig. 3. is the link-joint of the hose, T representing the pump-spout made of cast iron, and screwed to the pump-tree; *ee* is the collar or socket, made of brads, with the hose X bound upon it: this has two trunnions, on which a link, *f*, is fitted, one on each side; these links pass through grooves, in the cast-iron piece T, and a key *g*, put down through the link behind it, draws the joint tight, without any screwing or further trouble. The socket, *ee*, is fitted into the nozzle, and has a leather ring to make it tight. The outside of the pump is to be hooped at every three feet, to prevent it from bursting by the pressure of the water. The disposition of the three hand-pumps in a ship's well, renders their connection with a common receiver very convenient to bring all the water into one stream, which will then be very powerful, and more capable of extinguishing a fire than any moveable engine. Two hand-pumps are always placed on the starboard side of the main-mast, in the well, and one of them being the cistern pump used for washing decks, its foot stands in a small cistern fixed upon the step of the main-mast, and supplied with water by a pipe through the ship's side, with a cock to admit it at pleasure; there is one pump on the larboard side of the mast, three separate hoses being

united with each of the pumps by a link-joint, like *fig. 3*, at one end, and with three necks, *k, k, k*, of a receiver, *fig. 2*, by similar joints at the other, brings all the water into one, and a hose being joined by a link-joint, *l*, to the opposite end of the receiver, conveys the whole water to any part of the ship. The receiver has the three nozzles, *k, k, k*, at one end made in a divergent direction, agreeable to the directions in which the hoses came from the three different pumps, and a valve is placed withinside, before each nose, to open inwards, in order that the receiver may be used for one or two pumps, whilst the others are repairing, or getting ready, or that if any of the hoses burst, the water may not escape from the receiver at that nozzle. There are two handles fixed to the receiver, to lift and carry it, as it is to be moveable, and when in use, is proposed to be laid on the grating of the main hatchway, as the most central situation, from which the hose may be carried in any direction. Z is a branch pipe, or jet, screwed at the end of the great hose, X; and it also unscrews at the extreme end, to fit on jets of different bores, in the same manner as all other fire-engines. In working, the pressure of the water condenses the air contained in the receiver, O O P, into a small space, and its reaction to resume its former bulk equalizes the efflux of water from the nozzle of the pump.

In some experiments which we have witnessed upon this pump, it performed as well as could be desired, a single pump forming a very effective engine; but when the three were combined, it was superior in force to any we have ever seen, and would throw a stream, of an inch in diameter, over the main-top-mast head of a 74-gun ship. Besides, the length of the handle, C, admitting several men to work at once, an accession of force is gained by a rope, *n*, made fast to the brake A B, and conducted through a single block, hooked to the deck at *m*, and thence along the ship's deck. At this any number of men may be applied very advantageously, to produce the stroke, leaving those at the handle only to return it by lifting the handle. If the ship proves leaky, and the stuffing-box is thought to be an obstruction to the working of the pump, the air-vessel may be taken out, by drawing the wedges *d*, and taking out the bars R, which confine it; then after taking out the key which connects the joint-piece, *g*, with the copper rod, also removing the brake, lift out the air-vessel by the two screws of the stuffing-box, and fix on the joint piece again, but fix the guide-eye, H, in the lowest pair of holes, so that it will receive the top of the copper rod, and prevent the pump-spear having any play in the slings. In this state it acts as a common hand-pump, but the air-vessel can be restored to its place, and be ready for work in two minutes. To prevent any of the work being neglected from carelessness, the inventor proposes that one of the pumps shall be always used to wash the ship by the hose and jet in the morning, which it would do much more effectively than by the present mode of raising the water into buckets; and the force with which the jet of water is thrown would very completely wash into every recess of the gun carriages, and other places, where a brush cannot reach; while, by this constant exercise the pumps would always be ready at a moment's notice on an alarm of fire.

PUMP, *Air*, in *Pneumatics*, is a machine, by means of which the air is emptied out of vessels, and a sort of vacuum produced in them. For the invention, structure, and use of this pump, see *AIR-pump*; and for Smeaton's improved gage, see *GAGE*.

PUMPS, *Bare*, are small ones made of cane, or a piece of wood bored through, used in lieu of cocks, &c. to pump beer or water out of the casks.

PUMP

PUMP-*Cisterns*, cisterns of wood fixed over the heads of

Pyrites

PYRITES, *Sulfure metallique*, in *Mineralogy* and *Chemistry*, a name given to certain ores which contain a large quantity of sulphur, and have a metallic lustre. The Greek

word πυρίτης, formed of πυρ, *fire*, denotes fire-stone ; a denomination given to this substance on account of its inflammability. For the mineralogical characters of copper pyrites,

and iron pyrites, see *COPPER Ore*, and *IRON Ore*.

Besides these there are arsenical pyrites, auriferous pyrites, and tin pyrites. Combinations of sulphur with the metals are called by chemists sulphurets; and the different kinds of pyrites are properly metallic sulphurets. Sulphur has a great affinity for iron, and in combination with this metal, under the form of pyrites, exists in extensive beds in primary mountains, or is disseminated through the secondary rocks and strata, in veins and masses, or variously crystallized: it occurs also in beds of coal and bituminous clay. Iron pyrites may be considered, after the earths, as one of the most abundant substances in the mineral kingdom, forming a constituent part of the globe, and by its decomposition giving rise to many important subterranean phenomena.

The proportions of iron and sulphur in the different subspecies of iron pyrites enumerated by mineralogists are,

52 to 54 Sulphur
48 to 56 Iron.

Magnetic pyrites differs from common pyrites: its constituent parts, according to Mr. Hatchett, are,

36.50 Sulphur
63.50 Iron.

By the application of heat common pyrites becomes susceptible of attraction by the magnet; the excess of sulphur being expelled. Iron pyrites is not worked as an ore of iron, but is principally valued for the green vitriol or sulphate of iron, which it affords when exposed to air and moisture. Sulphur may also be obtained from pyrites when heated with charcoal.

The decomposition of pyrites is effected spontaneously by the absorption of oxygen from water and the atmosphere, which converts the sulphur into sulphuric acid, and the iron into an oxyd. These substances unite during the process, and form the sulphate of iron, or green vitriol.

Some kinds of pyrites are rapidly decomposed, others require to have part of the sulphur expelled by heat. The pyrites, or pyritous substance intended to form vitriol, is collected in extensive heaps, spreading the surface as much as can be conveniently done. The ground on which these heaps are spread should be impervious to water, and inclined, in order that the saline matter which effloresces may be washed off, and conveyed into reservoirs to crystallize. As the decomposition proceeds the mass becomes heated, and is occasionally moistened, particularly when the air is dry and warm. These beds continue productive for many years, and if the pyrites be pure, but little residuum is left. An excess of sulphuric acid is formed during the process, on which account a quantity of old iron is added to the solution, to saturate it, and obtain the salt in a crystallized state. During the decomposition of pyrites much heat is evolved, and a considerable absorption of oxygen from the atmosphere takes place. The fact was first observed by Henckel, who affirmed, in his "Pyritologia," that air was necessary to the process of vitrification, and that it enters into combination with pyrites and remains fixed in it: "non ut instrumentum transiens sed immanens." This may be considered as a happy anticipation of one of the most important doctrines of modern chemistry. Some geologists have supposed that subterranean fires, and the temperature of hot springs, are occasioned by the spontaneous decomposition of immense beds of pyrites in the interior of the earth, and an experiment made by Lemery gives some plausibility to this opinion. He found that a mixture of iron filings and sulphur, moistened with a small quantity of water, becomes hot in a few hours, the mass swells, and the parts adhere together: it then breaks with a

perceptible noise and crackling, and emits aqueous vapour, and a fetid odour like that of sulphurated hydrogen gas. If the mixture be made in a large quantity, it takes fire in twenty-four or thirty hours. As soon as the emission of aqueous vapour has ceased, the heat becomes greater and greater, is succeeded by inflammation, the smell is then much stronger, and appears to arise from the hydrogen produced by the decomposition of water. Beaumé, who observed this phenomenon from a mixture of one hundred pounds of iron filings, with an equal quantity of sulphur in powder, states that the flames rose to a foot in height, but did not continue longer than two or three minutes; the mass, however, remained red-hot for forty hours. Lemery the elder gave to this experiment the name of the artificial volcano.

Dr. Watson, in his *Chemical Essays*, vol. i. p. 187, says that he has repeated this experiment more than once. When made in the open air the flame is of short duration, and the whole mass, after the extinction of the flame, continues at intervals to throw out sparks. A ladle full of the ignited mass being dropped down from a considerable height, descended like a shower of red-hot ashes. The success of this experiment depends on a due proportion of water. Half a pound of flower of sulphur, with half a pound of clean iron filings, mixed with fourteen ounces of water, and worked into a paste, will acquire heat enough to make the mass take fire.

Some dark-coloured carbonaceous and bituminous earths contain pyrites in minute grains, and decompose with great rapidity when exposed to moisture. In the month of August 1751, the cliffs near Charmouth, in Dorsetshire, containing a similar kind of pyritous earth, took fire in consequence of a heavy fall of rain after a hot dry season, and continued at intervals to emit flame for several years. Almost all kinds of pit-coal in England contain more or less pyrites: in some the quantity is very inconsiderable, in other kinds it abounds so much as to render them unfit for domestic purposes, and totally inapplicable for forges or iron works, on account of the sulphur which they emit when burned. This pyritous coal may be distinguished by its greater specific gravity, and the brass-like metallic appearance of the pyrites with which it is intermixed. Pyritous coal and coal shale, or bituminous clay, containing pyrites, frequently take fire spontaneously in coal mines, or when exposed in heaps out of the pits, and continue burning many years. Influences of this kind now exist in the north of England; and so intense is the heat produced by the ignition of these masses, that the coal shale is sometimes fused. We have seen specimens from these heaps which have all the characters of cellular volcanic lava. In the vicinity of Leeds there is a large heap of coal shale which has been on fire near half a century; it is covered in parts with vegetation, and presents no appearance of ignition during the day; but if a dry stick be thrust into it the surface is changed in a few minutes. In some of the coal mines in Leicestershire, near Ashby de la Zouch, the stratum of indurated clay over the main bed of coal contains so much pyritous matter, and is so subject to spontaneous inflammation when it falls down and is intermixed with small coal and moisture, that the miners are obliged to close up the space with brick-clay where the coal has been worked, to prevent the access of air to the combustible matter. In this state, excluded from the air, the pyritous earth sometimes becomes ignited, as is evident by the heat communicated to the neighbouring parts of the mine; but the fire is prevented from spreading among the coal, by the precautionary measure of closing the cavities with clay.

The great heat evolved during the decomposition of

pyrites, may proceed in part from the combination of oxygen with the sulphur and iron, and may be increased by the different capacity of the new compound for heat. Whenever chemical changes take place rapidly, they produce a change in the temperature of substances, as in the well-known instances of lime and water, nitric acid and vegetable oils, &c.

The phenomena accompanying the mud volcanoes in various parts of the world, present many appearances which give probability to the opinion, that they proceed from the decomposition of pyritic strata. See *VOLCANO*.

The formation of alum is also effected naturally, in many situations, by the decomposition of pyrites, the sulphuric acid combining with the alumine of pyritous clay. Thus is not unfrequently the case in excavations of coal mines that have been long worked out.

At Hartlet, near Glasgow, in the excavations of an old coal mine that has been worked some centuries, there is a very extensive formation of alum, from the decomposition of the roof of the pit. It is a pyritous clay ten inches thick. In the old workings of the mine which are dry the air circulates slowly, and the roof gradually decomposes and exfoliates, and falls upon the floor, in which situation the decomposition proceeds, and the substance assumes the appearance of a spicular efflorescence. In time the whole space to the roof is filled; it is then removed. The mass consists of earth richly impregnated with sulphate of alumine, sulphate of iron, and in some instances with sulphate of magnesia. The coal in this mine, contrary to the usual practice, is worked to the dip, so that the old workings are always dry. To this circumstance may principally be attributed the great accumulation of alum in this mine. In many of the mines in England a similar formation of alum would take place, but they contain too much water to permit the saline substances to remain. In general, alum rock or alum shale require to be exposed in heaps, and burned in the open air, to expel the sulphur, and combine it with the oxygen from the atmosphere. The sulphuric acid thus formed unites with a requisite portion of the clay during the process.

The gypsum, or the sulphate of lime which occurs in beds, among secondary strata of red sand-stone and beds of marl, probably may owe its present state to masses of pyrites, which have existed over common lime-stone, and been decomposed naturally. The sulphuric acid thus produced would unite with the lime, and form gypsum. The great quantity of the red oxyd of iron which is in the stone and marl that accompany this kind of gypsum, gives much probability to this opinion. The crystals of gypsum or selenite found detached in beds of clay had probably a similar origin.

Sulphuret of iron may be formed by heating together iron filings and sulphur. From the experiments of Vauquelin it is proved that there are four sulphurets of iron, according to the degree of heat and other circumstances under which the combination may be formed. The first sulphuret consists of

78 Iron } Artificial.
22 Sulphur }

The second sulphuret, of

64 Iron } Natural magnetic pyrites.
36 Sulphur }

The third sulphuret, of

54.16 Iron } Artificial.
45.84 Sulphur }

The fourth sulphuret, of

47 Iron } Natural common pyrites.
33 Sulphur }

When the quantity of sulphur does not exceed 40 per cent. pyrites is soluble in muriatic acid, and may be rendered permanently magnetic. The specific gravity of common pyrites is from 4.60 to 4.83. Of magnetic pyrites 4.51.

Arsenical pyrites, called marcasite, is distinguished from iron pyrites by its colour, which is a silver white, and by yielding a smell like garlic when rubbed or exposed to heat. See *ARSENIC Ores*.

Auriferous pyrites, or iron pyrites, with a small alloy of gold: the richest specimens of this ore in Europe are found in Transylvania, containing from 0.02 to 0.03 of gold. These ores are distinguished from iron and copper pyrites by their colour, malleability, and specific gravity.

Tin pyrites. See *TIN Ore*.

The pyrites, in substance, are never used medicinally; nevertheless, in their products they are very important. From these common sulphur is extracted, in Sweden and Saxony; the native vitriols are produced in caverns of the earth, or on its surface; the greatest quantities of artificial vitriol are prepared; and the mineral waters, vitriolic, aluminous, sulphureous, hot or cold, are supposed to receive their impregnation.

When the matter of the pyrites is mixed with the lead ores, the method of separating the metal by assaying is this: roast two centners of the ore, as in the usual method, and keep a stronger fire than when the ore is pure. The pyrites, especially when it is merely iron, hinders ore from easily growing clammy or turning into large lumps, or entirely melting. When the ore is sufficiently washed, let it cool, beat it to powder, and repeat the roasting to a third fire, till when it is red-hot in the fire, there is no smell of sulphur; then mix the ore with six centners of the black flux, and two of sandiver, and finish the work in the common way, only making the fire greater, and continuing it longer, toward the end of the operation. Cramer's Art of Assaying, p. 292. See *LEAD Ore*.

PYRITES is applied by some authors to the marcasite ores of all metals; the names of which are varied according to the metals they partake of.

Thus *chryssitis* is that of gold; *argyritis* that of silver; *sideritis* that of iron; *chalcitis* that of copper; and *molybdenitis* that of lead, &c.

Quarry

QUARRY, in *Agriculture*, the common name of an opening, pit, drift, or shaft, which is dug into the earth or ground, and from which are to be raised ores of various kinds, different sorts of stones, slates, and other materials of similar natures. It is remarked by the writer of the work on "Landed Property," that the more useful and advantageous materials and substances that have at different times been dug and raised out of quarries in this country, are chiefly those of the iron ore kind, lime-stone, and other calcareous matters, materials for building, such as slates, flags, stones, and substances of other sorts, matters for the constructing and repairing of roads, as sand, gravel, and others of the same nature, earthy substances for the purposes of different manufactures, such as clays, &c. moulds and vegetable earthy matters, and coals, with other articles for use as fuel. There are, however, occasionally raised from openings of this nature, a few other kinds of substances,

such as will be noticed below.

It has been farther supposed by the above writer, that the substances which he has here mentioned, may with truth be said to be of more real use and value to mankind than all the mines of precious metals in the world; and that the eyes of the managers of landed estates should constantly be turned towards and fixed upon the discovery of the hidden valuable treasures and productions of this nature, wherever there is a probability or likelihood of their being to be met with. It is also suggested, that it would be highly beneficial and advantageous if mineralogists, and those who are acquainted with such substances, were to turn their attention towards the appearances or accompaniments which point out such useful concealed matters; as it might greatly facilitate the search for them, and frequently lead fortuitously to their discovery. The methods which are practised in searching for and ascertaining the presence of different sorts of mate-

rials of this nature, are principally those of boring, by means of an auger or borer made for the purpose, into the earth, and digging into it in other ways. In searching for most sorts of mineral substances, coals, and some other matters, the use of the borer is constantly first had recourse to, and not that of sinking a shaft, however favourable the appearances of the place may be for the purpose, and the success of the undertaking. The ground is first tried by this means, and a certainty of success or failure gained, as well as that of the most proper situation for sinking the shaft or making the opening or pit, without much expence being incurred, in case of the former. In trying for ochres, marles, and other similar articles, the same implement is also in common use. But in raising and providing lime-stone, free-stone, flags, and slates, &c. in some cases, digging down into and opening the ground, by spades and other tools, is the mode employed in the first instance, in consequence of such substances being obviously present in sufficient quantities to be wrought with advantage. See *BORER, BORING, and AUGER.*

The common methods of working and managing different sorts of quarries, are in general, in most places, tolerably well understood and regulated, by such quarrymen as are constantly employed in the business; but a circumstance which they commonly neglect very much, or are in a great degree inattentive to, in many cases, is that of making good the ground below, by means of the turf or soil which is cast off from the top, or upper parts; and that of keeping the mouths of the openings sufficiently clear and free. Another common difficulty incident to them, is that of draining, and freeing their bottom parts from injurious water. This may be effected in various ways, as by the use of different sorts of machinery worked by wind, water, and steam, and by some other means. See *QUARRIES, Pits, &c. Draining of.*

In many of the more southern districts of the kingdom, and still more in those towards the north, and in Wales, there are quarries, from which substances of some of the following kinds are raised and used in their neighbourhoods, or sent away to a distance, in a very extensive manner; such, for instance, as those of the stony kind, as iron-stone or ore, lime-stone, marble, chalk, granite, free-stone, grit-stone, flag-stone, white, grey, purple, and blue slate-stone, sand-stone, sand, gravel, clay-stone, scythe-stones, tile-stones, &c.; different ochres, plumbago or black lead, calamine, gypsum, marle, pipe-clay, alum-earth, fuller's-earth, peat-earth, culm, coal, cannel, salt-rock, &c. These quarries and pits are wrought, and the materials got up from them, in several different ways, according to circumstances and convenience, as well as the particular nature, kinds, qualities, &c. of the different articles themselves; all of which are mostly well known, and capable of being performed by the workmen of their respective neighbourhoods, who are commonly employed in them, and very expert in their management.

Stony substances which bear a great variety of different names, and which possess equal variety in their qualities and useful properties, are met with, and dug up from quarries and pits, in many different districts and situations, in almost all parts of this island, in order to be converted to purposes of improvement and utility in a variety of different ways and intentions. Iron-stones and ores abound more in the northern parts, though they are occasionally found in some of the southern ones. A considerable quantity of highly rich iron-stone is got up and sent annually from the vicinity of Combemartin in Devonshire, to the iron-works of Mr. Raby at Llenethy in South Wales. A large portion of it is also found on the borders of the Orchmont river, and dispersed throughout the whole district, as well as in other parts of the same county.

Iron-stone is likewise met with in Suffex in large quantities, imbedded with lime-stone and sand-stone, that which rises near to the surface being the best, the other having a coarser and more dull appearance, working heavier in the furnace. The very best is frequently intersected with thin stripes of soft marly matter. Iron-stone, to a great extent, exists on the estates of lord Dudley, and many others in Staffordshire, and contributes much to the employment and prosperity of the inhabitants. But, in the northern part of Lancashire, in the district of Low Furness, stone and ore of this sort are perhaps found in the largest quantity, of the best kind, and in the most general manner, of any where in the kingdom. There are numbers of shafts, quarries, and pits for raising them from, on Lindal Moor, Whitrig Moor, and Cross Gates, in the vicinity of Dalton, as well as in some other places. In the former, the working is usually effected at the depth of from twenty to forty-five feet, but it has been done at less as well as greater depths. The whole of their cavities are chambered with wood, and cost from a guinea to twenty-five shillings in sinking each fathom, without the wood. The ore runs in veins or seams between the rocks on the north and south, being in breadth from about forty to sixty yards. And it constantly dips towards the south-east at the rate of about a foot in five or six. The best ore is that which has the most greasy appearance, and it is raised with less difficulty, working less hard, requiring less flux, and forming a more soft iron. It is raised from the shafts or pits by machinery of the gin or windlass kind, the men employing picks, punches, and hammers in digging it up. It was formerly got, in some places, by driving levels into the sides of the hills, and conveying it out on railways, in small waggons; but now the other way is mostly employed. Four men get about fourteen tons in the day, in some situations; but in others, double the number are required for getting the same quantity. It is wheeled to distant heaps, from which much of it is sent in small carts to the port of Old Barrow, from whence it is shipped to different parts of England, Wales, and Scotland, at the expence of from fourteen to thirty shillings in freight; and the rest converted into pig-iron by the furnaces in the neighbourhood. Iron-stones and ores are also met with in some other counties more to the north of the kingdom, where there are pits and quarries for raising them from.

Lime-stone is a very general sort of stone raised from quarries and pits in many different parts of this country, as in Devonshire, Suffex, Kent, &c. towards the south, where it lies in vast beds, from which it is dug for use; in the more midland counties, as in Gloucestershire, Shropshire, Derbyshire, Staffordshire, and others, where it exists and is employed to a still greater extent; but by far the most extensively in those farther to the north, as Lancashire, Westmoreland, Yorkshire, Cumberland, and some districts of Scotland. In many parts of the county of Lancashire it is dug and raised from quarries, where it lies in a stratified manner at no great depth from the surface, being got up without much difficulty or trouble; while in other places it is forced from the solid rock, with great labour and expence. This is likewise the case in many other districts. Wherever it is met with, it is almost constantly a quarry material of great value, and which affords much employment to labourers.

In the county of Kent, the banks of some of the large rivers are scooped out into stone quarries in a remarkable manner, some of them worn out and disused, others in the state of being wrought. It has been observed, that this is the nearest stone country into which water-carriage can penetrate from the metropolis; and that the original London

was built, as well as the modern one chiefly paved, by materials from this district, such as the rag-stone, and the large pebbles gathered on the sea-shores, before the Scotch granite came into use. In the neighbourhood of Maidstone there are the appearances of many abandoned and neglected quarries of this nature; but the most considerable ones, which were lately wrought in that vicinity, are those of Farleigh and Fant. In each of these, blocks of stones, of different kinds, and of every form and size, are met with, being separated by seams, and large irregular masses of earth of various qualities: among the rest, brick-earth of the best quality. In some places, the stones are buried several feet under these earthy materials; in others, the rock rises to the surface. After this, the quarrymen worm their way; following it, with irregular windings, leaving behind them refuse in greater quantity than the useful materials which they raise.

The stony substances which are principally met with in them, are of two very distinct kinds: the one hard, and of a strong contexture, provincially denominated *rag*, or Kentish rag; the other of a soft crumbly nature, provincially termed *hassock*. The quarrymen are in the practice of dividing the first sort into two kinds; what they call the *common rag*, and the *cork-stone*, the latter being their principal object in these immense works. It has in its general appearance much resemblance to the strong grey lime-stones which are found in different parts of this country; but when minutely examined by means of a glass, its fracture and contexture have the characters of the Devonshire marbles; except that the grain of this sort of stone is somewhat coarser. In colour, too, it differs from these marbles, having a greater resemblance to the Yorkshire lime-stones. It is used for different purposes; much of it is sent to the neighbourhood of London, where it is burnt into lime, for the use of the sugar-bakers; who, for some reason or other, chiefly employ lime, burnt from this material, or stone, instead of that of chalk. It is likewise made use of as a building material; and, particularly in pedestals, for the posts of cattle-sheds and other farm-offices. It is hewn with stone-masons' axes, working with tolerable freedom.

It is very durable, as some part of the basement of Westminster Abbey appears to have been built with the stone from these quarries. In this case, it seems to have been dressed smooth; and the surface still remains with little alteration; having withstood the attacks of time with great firmness; it being even now difficult to detect a loosened splinter in the work.

The common rag-stone comprehends all the different kinds which are met with in these quarries, except that of the above, and that which is of the hassocky nature; though the true unmixed rag is a distinct sort, having characters different from any of the others. In the colour, it inclines more to the red or liver colour, than that of the cork-stone, but otherwise resembles it considerably. Viewed with a glass, its grain is finer, and the fracture flint-like.

Its uses are, however, but few. Some of the best and most regularly-faced stones are sometimes laid aside for paving materials; but the large pieces are mostly reserved, in order to be sent by water to the district of Romney Marsh, for the purpose of forming the hard materials of the embankments and jetties, which are there made against the sea. The smaller sorts are, in general, converted to use as a road material.

The hassocky stone appears to the naked eye to be of a soft, white, sandy quality; and its fracture is the same. But under the glass, its grain is fine, its contexture uniform, and so thickly interspersed with small seed-like granules,

of a dark or black colour, as to give it a grey appearance. Sometimes bearing evident impressions of shells. Its texture is loose and brittle; crumbling easily between the fingers into a coarse sand-like powder. It will not burn into good lime, although it is almost wholly calcareous.

Its principal use is that of forming a loose friable sort of rubbly sub-soil, in some places, which is admirably suited to the growth of saintfoin, and some other crops of the plant as well as the fruit-tree kinds.

The quarries in several other counties contain stony materials of these different kinds, which are wrought and applied to a variety of different uses in these and other ways.

Quarries of marble are wrought in several districts in different parts of the country, and afford great advantages in various ways. In Sussex they have a marble, which, when cut into slabs, is used for ornamenting chimney-pieces, and many other purposes. It is equal in quality and beauty to most sorts when highly polished. For square building and paving it is also a material scarcely to be exceeded. By burning, it likewise affords a very valuable manure, equal, and by some thought superior, to chalk, being cheaper to those who are near the places from which it is dug. It is found the most perfect about Kirdford, at the depth of from ten to twenty feet underground, in flakes nine or ten inches in thickness, and called the Petworth marble. It was much employed in building the cathedral at Canterbury, the pillars, monuments, vaults, pavement, &c. being formed of it. And the archbishop's chair is one entire piece of it. Marble is gotten in some of the counties in the middle of the island, as Derbyshire, Nottinghamshire, &c. At Beacon-hill, near Newark, a blue stone for hearths is got, which approaches to marble, and is capable of burning into lime. And in the county of Derby much good marble is raised in different places. In Lancashire there are quarries of fine black marble, and of stones, which approach to, and take on the polish of marbles. In many of the western and northern parts of Yorkshire, marble of various kinds is found, some much resembling, and others superior, in closeness of texture and distinctness of colours, to that which is wrought in Derbyshire. Also a stone, which greatly resembles the marble of that county, and which is capable of receiving much such a polish, and is nearly of the same colour, mixture, and appearance. On the side of the river Kent, near Kendall, a vein of beautiful marble has been lately discovered in the property of D. Wilson, esq. of Dallam-Tower; and a main quarry opened upon it. Marble has also been met with on the opposite bank.

In the county of Inverness, likewise, marble of the greatest variety of colours, and of the most beautiful shades, has been met with in Benevis, on the property of Mr. Camerton; and inexhaustible quarries of it lie untouched in the islands which belong to it.

Besides, this sort of material exists in immense quantities, in quarries, in many other parts of the kingdom.

Chalk is a material which is raised from quarries and pits, mostly in the southern parts of the country, as in Sussex, Surrey, Kent, Essex, Berkshire, Hertfordshire, &c. It exists in vast ranges and tracts in most of these districts, whence it is dug up from quarries, at different depths, according to circumstances, exposed in sheds to dry, when wet, and then converted into lime for various uses, by means of fire, or employed in its broken and powdery state, without undergoing the above processes, by merely digging it out of such places. In some parts, as in Kent, and the neighbouring districts, it is often dug and raised from considerable depths, from beds of very great thicknesses. And near Reading, in Berkshire, there is a stratum of this sub-

flance, which is thirty feet in thicknefs. It is there used and dug out for manure, and occasionally as a building material, for the latter of which purpofes it is very durable. The remains of the abbey of Hurley, and of the ancient chapel, now the parifh church, built wholly of chalk, in the reign of William the Conqueror, are, it is remarked by the writer of the corrected Agricultural Survey of the diftrict, ftill as frefh and found as if they had been the works of the laft century. Chalk, when once indurated by the air, has a remarkable property in refifting the action of the weather.

Granite is a ftoney fubftance, which is found to exift in fome of the fouthern parts of the country, as well as in thofe of the north, but it abounds much more in the latter.

In the weftern parts of Cornwall it is in great plenty in the diftricts of Penwith and Kirrier, prefenting itfelf in large flabs on all the rocky hills or tors, as well as in the waite moors and vallies; and appearing in detached fpofts, even in the fhelfy flaty trafts. It is of different colours and textures, being adapted to a great variety of ufes and purpofes, as thofe of building, and being wrought into columnar mafles, eight or ten feet in length, for fupporters to fheds, out-houfes, &c.; and as gate-pofts, and bridges over brooks, rivulets, &c.; as well as in the forming of rollers, malting, falting, and pig troughs. It is alfo an article of commerce to different parts. It is fuppofed to be exactly of the fame nature with the original granite; and there are five forts of it, which are diftinguifhed by their colours, the white, the duiky, or dove-coloured, the yellow, the red, and the black, moft of which are charged with a brown and bright filvery matter.

The county of Invernefs has a great deal of this fort of ftone, and there are numerous quarries in it for raifing and working of it. The common granite abounds in all the different diftricts of it. In many places the whole rocks are compofed of this kind, which is uncommonly ufeul for all ordinary purpofes. By natural fiffures, which run in ftraight lines, and generally at right angles, it is formed into all fized portions and fhares, having uniformly a plain furface. And, by means of cutters or tranfverfe lines, thefe ftones are eafily quarried, and found in the greateft plenty every where. They are remarkably beautiful, being almoft as fmoother and regular as hewn ftone, and of courfe well fited for various forts of building work. The belt buildings of the county-town are of a dark kind of granite, which is very hard and durable, but which has few or no fiffures. It is generally found in large blocks, and in many of thefe parts, there is no other material for building or adding ornament with. The manner of giving it the polifh it admits of at the quarries, is by means of fmall picks, or pick-axes, which are, in fact, hammers with fharp points at each end, in the manner of thofe employed by millers in preparing their grinding ftones. It is a very heavy, compact ftone. There is a mixed fort, denominated peafy granite, which confifts of white, black, and grey fpofts, that fparkle beautifully in the fun, and is very ornamental, as well as much ufed for different purpofes, as ftairs, doors, and windows. Though this is very folid, and almoft without natural fiffures, it fplits very ftraight, by means of iron wedges, fet in a line, and ftruck alternately, with a hammer of great power.

A great deal of this kind of ftone is imported into the metropolis and other large towns, for paving the ftreets, &c. It is on the whole a very advantageous fort of quarry material in various parts of the kingdom.

Quarries of free-ftone are wrought in a great number of different places. In the more fouthern parts is found the

Portland ftone, which is fo famous and ufeul in building. A fort of this kind of ftone, which much approaches to it in quality, is alfo met with in Cornwall. Some likewife exifts in Devonfhire and Gloucefterfhire. The Cotfwold quarries in the latter, afford free-ftone of an excellent quality, particularly thofe at Painfwick, Lodbury, Lockhampton-hill, &c. It abounds more, however, in Chefhire, Lancafhires, Westmoreland, Cumberland, and fome of the ftill more northern diftricts. Several excellent quarries of free-ftone are carried on in the firft of thefe, as thofe at Runcorn, Manley, &c. where much valuable ftone of this nature is raifed. The fecond county alfo affords equally valuable quarries in many different places, from which vaft quantities of the ftone are raifed, and employed, or fent away to a diftance. Thofe about Ormskirk, Up-Holland, and Wigan, as well as thofe on all the eaftern fide, are in general of a very good quality. And in the vicinity of Lancafter there are fome excellent ones; that on the moor or common, clofe to the town, is very extenfive, and affords a free-ftone that admits of a fine polifh. In this diftrict, this fort of ftone is met with of a whitifh-brown, yellowifh, and reddifh caft, but the firft is by much the moft efteemed. In the eaftern parts of Westmoreland, as about Hutton Roofe, and fome other places, a good fort of free-ftone is dug up from pits and quarries formed for raifing it. This fort of ftone exifts and is quarried almoft all over the counties of Cumberland and Northumberland; and prevails occasionally in others, where it is wrought to advantage. A grit-ftone, fomewhat of this nature, is met with in fome diftricts, as in Shropfhire, &c. which is raifed from quarries, and ufed as a building material. And a fand-ftone exifts to confiderable extent in others, as in Suffex, &c. that is fometimes dug up, and made ufe of for common buildings, &c. In Chefhire, on the hills near Macclesfield, about Kerridge, a fort of fand-ftone is met with, which is particularly well fited to the making of flags, and whetting tools, as well as fometimes to the forming of flates, for which it was formerly much employed. Near Pott-Shrigley, alfo, a fine fand-ftone is found, that admits of a good polifh. The quarry has not, however, been wrought for fome late years, as from the extreme hardnefs of the ftone, the expence of getting it is very confiderable. There are feveral other quarries of excellent free-ftone wrought in the fame neighbourhood.

There has been great abundance of free-ftone wrought, time immemorial, in the low parts of the county of Perth, and quarries of a greater or fmall grained ftone of this fort appear almoft in every place, with the exception of the carfes. In the lowlands, and near to the eaftern fea, the pores and grain of it are greater; but as the mountains are approached, the pores are lefs, and the grain finer, by which thefe ftones admit a fmoother polifh. The quarry of Tul-yalan parifh, called Long-annat, affords a ftone of a very excellent quality. It has a white colour, admits of a fmoother polifh, and refifts the influence of the weather. Some of the principal houfes in that part of the country, as well as fome of the moft magnificent public buildings in the capital of Edinburgh, as thofe of the Exchange, the Infirmary, and the Register-office, confift partly of this ftone, and thofe found at hand. And farther, in fome inftances it has been carried to the continent. But the quarry of Kingoodie, in the carfe of Gowrie, belonging to Mr. Mylne, of Mylnfield, is unqueftionably the fineft of this kind of any in the county. Altonifhing blocks in great number are raifed there, fifty feet in length, fixteen feet in breadth, and three feet in thicknefs. Such is the demand for this ftone, both at home and abroad, that four veffels are employed in exporting it from this quarry. The work is, however, on the de-

cline, occasioned by the act of 1794, which imposed a duty on stones, which, although trifling in itself, causes much grievance, vexation, delay, and trouble, in procuring coal-dispatches, &c.

Flag-stones and quarries for the working and preparing of all sorts of flags, are met with in all those situations where free-stone is found, and where it exists in rather thick strata, or layers of some depth, which are capable of being separated by hammers, wedges, or other means. In many places in the southern parts of the island, the flags raised from such free-stone quarries are of an extremely good quality, being used in very large quantities for many different purposes. Those of Cornwall and Devonshire also, in many cases, afford a good sort of flags. The sand-stone quarries of Shropshire, as at Grinell, near Shrewsbury, about Bridgnorth, and at Corndon-hill, near Bishop's-castle, as well as in the Swinney mountain, &c. where alternate beds of fine white and red stone of this kind, of very superior quality and thickness, exist; that in the first of these situations, being twenty yards thick, affords flags likewise, which are of a very useful nature. Free-stone flags too, of useful sorts, are met with in the quarries of some of the midland counties. And they abound much in many of the free-stone quarries of Lancashire, Yorkshire, and some of the other more northern districts of the country.

The quarries of this kind become slate-stone, and furnish the white, grey, and brown slate, wherever the stone lies in thin layers, or strata, which are able to be raised and separated from each other with convenience and facility. They exist in most of the above tracts, and are plentiful in some of them, especially those towards the north. The Lancashire and Yorkshire quarries, in many places, supply the white and grey sorts in great abundance, and of good qualities. Those of Westmoreland, Cumberland, and Northumberland, also afford them in many instances of a valuable nature. And they are equally good in the still more northern districts. There are numerous quarries of different colours of them in Clydesdale, Perthshire, Argyleshire, and the county of Inverness, from which vast supplies are constantly raised for home and other use. This sort of slate has, however, mostly the disadvantages of being very porous, heavy, less durable, and of requiring more and stronger timber to support it, than some other kinds; being only fit for exposed climates and situations.

The quarries of the lighter and thinner kinds of slate, of the blue, green, purple, and other colours, formed from other sorts of stone, only exist in some particular districts, as those of Wales, the northern part of Lancashire, and the adjoining counties, and in a few places in Scotland. The slate quarries of the Welsh districts supply several kinds and colours in large quantities, and of good qualities, but the dark and lighter purples are the most prevalent sorts in most of them. In Lancashire the quarries of this kind are very numerous in the part to the north of the sands, as about Gothwaite-common, Kirby-moor, Conistone-hills, and Tilberthwaite-fells, &c.; and from which very large supplies of the blue, green, and the dark purple sorts of slate are raised, and sent away for exportation, or consumed at home for different purposes. They are wrought, and the slate prepared in somewhat different manners in different places. The Gothwaite quarries have the slate dug out from the side of the hill, and carried away. But in some on Kirby-moor, a level is driven through the ground from below, the metal being conveyed away by small four-wheeled waggons on iron rail-ways. Those about Conistone are mostly worked into the hills, and the metal raised and carried out from them. Some of the Tilberthwaite quarries are wrought

by blasting the slate-stone, and collecting and carrying it out of them on slanting roads, in small carts or trucks constructed for the purpose, the levels being below the hills, but not nearly so low as the bottoms of the quarries. Others are wrought by draught roads from the bottoms of them. One man will raise eighteen or twenty hundred weight of slate in one day, where the metal lies well, but less in other cases. In some it is dug out by one set of men, but by another, and formed into slates by a third, for which purposes, flat crow-bars, slate-knives, and axes are employed. The slate is divided and distinguished into three sorts, as firsts, seconds, and third, or London, country, and tons. In the first, or Gothwaite quarries, the slate has a darkish purple, or black cast, and is worth from forty to forty-four shillings the ton. In the Conistone quarries it has a fine blue and green appearance, and is much thinner and lighter than the other sort. The Tilberthwaite slate, in some instances, splits very fine, thin, and light, but does not cover so far as those of the Gothwaite and Kirby quarries. This sort is worth from forty-eight to fifty shillings the ton. In some quarries a sort of rent is paid per ton, on the slate which is raised, as ten shillings for the best, eight shillings for the seconds, and sixpence for the thirds. In others a certain rent only is paid for the liberty of the royalty, and not a tonnage duty. These rents or duties on the workers of these quarries, are probably higher than they will bear, and have enabled the Welsh slate dealers to undersell those of this county.

Westmoreland and Cumberland, in some instances, afford good blue and green slates. In the latter, some of an excellent quality are gotten in the quarries of Borrowdale, and inferior sorts in some of the neighbouring mountains.

The county of Argyle, in Scotland, in some parts abounds with slate-quarries, as the tracts about Eldale, from which five millions of slates have for some time been annually sold at the rate of twenty-five shillings the thousand. Quarries of the same kind are also wrought in many other parts, with great benefit to the inhabitants.

Slate-quarries are formed in many parts of the highlands of the county of Perth, but none in the low. The slates in some are of a purple colour, in others of an azure blue, and in a few of a muddy, sandy, brown complexion along the cutters. It is well known where the different sorts are quarried. The veins of slate-rock seem to run from Drum-lae, in the parish of Aberfoil, in a north-east direction to Dunkeld; and may be traced beyond the limits of the county both ways. The azure coloured are the best metal, and rite of a greater size than any of the other kinds. Many of the buildings in different places are slated with this beautiful covering. Into the lower districts of the county, slates are imported from Eldale, and the other quarries on the west coast of the county of Argyle.

Quarries of grey slate exist in many different parts of the county of Inverness, in which the quality is very good, and well suited to the climate. In some places these slates are much preferred to blue ones, as the latter are more expensive in procuring, and though nailed on the roofs ever so firmly, are apt to be loosened by high winds, unless bedded in lime, which circumstance renders repairs difficult.

There are numerous quarries of sand and gravel to be met with in almost every district of the kingdom, which are wrought either for the purpose of supplying domestic uses, or those of repairing roads, &c. Those of the former sort, which contain the fine white, red, and yellow sands, are by far the most valuable, and wrought to the greatest extent, the materials being mostly dug out from the sides of banks and other places, and but rarely got by sinking

the quarries into the more level parts of the ground, though this method is sometimes practised. The matters are commonly raised simply by digging and spades; and thrown into the carts, in many cases, from the quarries and pits themselves. Numerous quarries and pits of this nature exist and are wrought to a very great extent in the neighbourhoods of the metropolis, and most other large towns, all over the kingdom, for the purpose of sale for various domestic uses.

In the gravelly kinds, those quarries which abound with the sharp, coarse, flinty, and pebbly sorts, are the most proper and beneficial for the making and repairing of all sorts of roads and carriage-ways. They are occasionally formed by working into banks and steep places, but more frequently by openings in the plain surface. Their depth is sometimes considerable, the materials being raised after being screened, the work, of course, very laborious and troublesome. In other cases, the carts are filled from the quarries or pits without much difficulty or trouble.

Quarries of clay-stone, stone-tiles, scythe-stones, and some other sorts, are found of good qualities in different districts. In Gloucestershire they have quarries of blue clay-stone at different depths, lying in beds of the same coloured clay, disposed in layers of from four to ten inches in thickness. The stone in new quarries is estimated by the effects which the atmosphere has upon it from some exposure. The best sort is a very useful material for several purposes. Quarries of stone-tiles principally exist, and those articles are raised from them, in different parts of the Cotswolds. The best are prepared about Miserden, Beverstone, Charlton, and Hampton-field, the colour of which are yellow or grey; but another sort, which is red grit, is dug up about Iron Acton, and some other places, but which is less valuable.

There are quarries of scythe-stones in many parts of Lancashire, but the best are obtained from those about Rainford, where they are well wrought and prepared for use. In several other districts, quarries of different kinds of whetting-stones likewise exist, and are wrought to advantage.

Ochres of different kinds are met with in different places in quarries formed for the purpose of raising them. In the county of Devon, formerly large quantities of various shades between red and yellow, were raised and manufactured in those about East-down. Umber, in the parish of Combemartin, exists in a pretty large body. The working and preparing of these are, however, now much less attended to than heretofore.

In Sussex there are quarries of red ochre about Graffham, and in various places contiguous to the sea, as near Chidham, &c. where much is raised, prepared, and sent to London. Ochre quarries also exist in many counties more to the middle and north of the kingdom, from which great quantities of this substance are procured and prepared for use in different sorts of arts and manufactures.

Quarries of plumbago, or black lead, are likewise occasionally found and wrought, in different situations, in different districts of the country. This substance has been met with and raised near the borders of the Bovey river, in Devonshire, in some quantity, and prepared to be sent to Exeter for sale. Quarries of black lead are also found and wrought in Borrowdale, in Cumberland, near to the town of Keswick, to some advantage. And they exist in some of the middle tracts of the island, affording great benefit to the proprietors of them. In the county of Inverness, there are some appearances of black or pencil lead about Glengary, but they have not yet been turned to any useful account.

In some districts, in the middle parts of the country, quarries of calamine, or *lapis calaminaris*, are met with, and much of this substance raised from them to great profit. It abounds in the Mendip-hills, in Somersetshire, about Rowbarrow, Shipham, Winscomb, and on Broadfield-down, &c. It is sometimes found within a yard of the surface, and seldom wrought deeper than thirty fathoms. In some places its quality is excellent. It is present in other neighbouring mountainous tracts, and raised with equal advantage.

Quarries of gypsum present themselves in many different parts, and are wrought in some with considerable benefit. In the county of Devon, it lies between strata of red-stone, marle, and chalk rubble, about Salcombe, Branscombe, and Beer, being useful for various purposes. Gloucestershire and Derbyshire have quarries of this nature, where there are fine beds of it. Those of Aust Cliff in the former, have it not so good, however, as that which is met with in the latter county. In Nottinghamshire it is of an excellent quality, especially that got near Newark and at Redhill. Cheshire has some, but not turned to much account. Westmoreland and Cumberland have good quarries of it, in some places, where a great deal is gotten up, and made use of. And it abounds in different parts of the county of York, where it is raised to advantage.

Marle is an article that is met with in pits and quarries in a variety of different situations, and of several different kinds and qualities. It is found and dug up for use in many places in Sussex, and the counties more to the centre of the country; but it prevails in the greatest plenty in the county of Lancaster and some others, in which it is raised or worked out from large openings on the sides of hills, high banks, or in the plain surface, and set thickly upon the land. The getting or digging of the material out of such places, is usually performed by means of strong iron mattocks, crows, spades, and wooden spiles; large pieces being in some cases forced down, not without danger to the workmen, by driving in the spiles or piles from above. This method is called *falling*. The work is extremely severe, and commonly done by the rod. The large clods thus forced down, break into small pieces, and are then filled into carts for the purpose.

Shell-marle, though it is not much attended to in any part of England, is frequently met with and dug up from various parts of Scotland, and employed on the land in great quantities, with much success. The pits and quarries of this sort are commonly wrought with much more facility than those of the others.

Pipe, and other kinds of fine clays, are dug and raised from a sort of pits or quarries, in large quantities, in many different counties. Near Wear Giffard, in Devonshire, much of the first sort is dug and sent coastways, though not in such quantities as formerly. Brown potter's-clay is also raised and sent away in great abundance from the neighbourhood of Fremington. These sorts of clays are likewise found in much abundance in Berkshire, and still more fully in some of the midland districts, where the pits of them are wrought to a vast extent. They are articles of great importance and utility in several sorts of manufactures, and for which there is great demand in many instances.

Alum earth is a kind of stratified matter, which is met with and raised from pits and quarries in a number of different situations, and various parts of the kingdom. In some they are wrought to very considerable extents and advantages, but in others in far less degrees, and with much less success.

The strata of this earth are dug and got up in different

manners under different circumstances, but mostly by means of strong crows, picks, and other tools of a similar kind, being wrought in somewhat the same method as in the cases of marle. The business is usually executed by common labourers.

Fuller's-earth is another material of this nature, which is dug out of the ground from pits and quarries at different depths in several parts of the country. In some it is very abundant, and of a rich good quality, as in those of the middle and more northern parts of the island, forming an article of great use and demand in several branches of business. In others it is of a much less valuable nature, being far less in request. That which is found about Tillington, in Suffex, is consumed in the neighbouring fulling mills. The mills of this sort in Yorkshire, and other parts also, consume immense quantities. The material is raised from the places in which it is found in much the same way as many other earthy substances, but it seldom requires so much digging, as it is a far less hard matter.

Fuller's-earth was formerly got up from pits and quarries in the neighbourhood of Maidstone, in Kent, and much ground wrought over; but the beds of sand by which it is covered are of such depths, as to render the works of little value or importance.

Quarries and pits of mineral peat-earth are found in some districts, and much of the material dug up from them, and made use of when prepared upon land. The vale of Kennet, in Berkshire, contains vast quantities of it, as well as some other parts. It is a stratified substance which is dug from under the surface at the depth of from one to six feet, laying below strata of small shells and calcareous matter. In raising it, a peculiar kind of spade is made use of, which cuts it in long pains, something like soap, which, when dry, are burnt into ashes and laid on the land. This substance is found to contain the oxyd of iron, gypsum, and the muriates of sulphur and potash, in the proportions of forty-eight, thirty-two, and twenty parts to that of one hundred.

It is suggested by the writer of the work on "Landed Property," that in most mountainous districts, and many low fenny counties, immense collections of vegetable mould or peat-earth lie in a state of neglect; even in places where they might be converted to valuable purposes; not only as sources of fuel merely, but as manure, either using the vegetable matter in its raw state, or after being reduced to ashes. In all these situations it might be readily dug up from different places, and applied to different uses in each of these ways, the pits or other spots containing it working in a very easy manner. The ashes of it are only employed on any large scale in the above county.

Culm, coal, and cannel, are articles of the fuel kind, which are found in a vast number of places, all over the kingdom in pits, mines, or quarries, and which are of the greatest importance in many of them. Speaking of coals, the author of the work on "Landed Property," considers them as rising in the minds of most men, far superior to most other productions and subterraneous matters, whether they are held in the light of agriculture, manufactures, or national defence. It is asked, if it were not for the collieries of this country, how many hundred thousand acres of its land, which are now appropriated to cultivation, would be required for the production of fuel? How many manufactories, especially those of iron, which are so very valuable to civilized society, would be cramped, retarded, and stopped, in their progress and operations? And how many hardy seamen would be wanting to its navy? Surely, in his opinion, an indigenous production and material, on which

the prosperity of the country so greatly depends, is entitled to the guardian care of its government; to ascertain the present expenditure, and the probable stock which is remaining. Let us not, it is remarked, play the spendthrift, and, by the follies of a day, entail centuries of want on generations to come, and the curses of millions on the memory of the present times.

In endeavouring to find these sorts of substances in parts or pits of them have not yet been wrought, the searching, it is supposed by the same writer, should, in general, be done by the land proprietors of the particular places, in conjoint manner. There are, however, certain instances, ... which individuals may prosecute the search with propriety, and in the most beneficial manner. In doing which, the principal things to be guarded against are those of misjudgment and imposition. Hence the necessary prudence of endeavouring to procure persons of skill and integrity for making such searches; which are, in the first place, to be attempted by a close investigation of superficial appearances, and then where those are favourable in their nature, by the use of the boring rod or tool. It is supposed that, at present, there are none who are equal to such undertakings, except those who have been long conversant with the business of coal-works; men who have an interest in the existing collieries or works of that kind. On this account it is thought to become a matter of common prudence, in a given situation, to endeavour to procure an undertaker or overlooker from a distant work; or such a one as can have no counter-interest to that of his employer; and then, closely to connect and bind them in one common interest. After having had different occasions for considering the subject, and for bestowing no small thought upon it, the writer is of opinion that the most eligible plan of proceeding, in such cases, is that of agreeing with an overlooker, or undertaker, to pay him reasonably, but not extravagantly, for his time, and for his actual expenses in prosecuting the necessary searches; and, further, to agree to give him, in the event of success, a reward sufficient to call forth his best exertions; such reward to be payable, not on finding coal, but whenever the work, to be established in consequence of the discovery, shall have cleared the amount. In this way the proprietor will feel himself secure, while the person employed has the most powerful stimulus to industry, attention, and the accomplishment of the object of the undertaking.

Culm and coal have been met with and wrought in some degree, in Devonshire, Suffex, and some other of the southern parts of the island; but they exist much more plentifully in the midland and more northern districts, as well as in some places in Wales and Scotland. In Gloucestershire, coal abounds in most parts of the forest of Dean, and its vicinities, and probably to within a small distance of the county-town, as at Newent and Pauntley, where pits are established. Those of the forest tracts are very numerous, but not fully wrought for want of sufficient draining. Pits of this kind also exist in many places, in the lower vale part of the county. In this district, however, the coals are no where of the best quality.

In the counties of Salop and Somerset, coals also prevail very much, various pits of them in both, being wrought to considerable extent. Those in the northern part of the latter district, have strata of them which form an inclination of the plane of about nine inches in the yard; and are nineteen in number. They are seldom wrought where less than fifteen inches in thickness, but they vary from ten inches to upwards of three feet. The working is performed at considerable depths, especially since the establishment of improved machinery, and other means for raising them. The

coal is of the first quality, being pure and durable in burning, and from its firmness, largeness, and strength of grain, capable of being conveyed to any distance without injury. At present the quantity raised in these pits, is from fifteen hundred to two thousand tons weekly, but much greater supplies could be afforded, if they were wanted. The works are twenty-six in number, some of which afford a good profit.

The pits in the southern part are upon a more limited scale of work. In them the strata of coal form an inclination of the plane of from eighteen to thirty inches in the yard; but in some it is destroyed, and they descend in a perpendicular manner. There are, in number, twenty-five, which are in thickness from six inches to seven feet, being rarely wrought under eighteen inches. The depth of working is middling, but will be increased. The quality of the coal not the best, but tolerably good. The quantity now raised from these pits is from eight hundred to a thousand tons in the week, which might be easily extended. The working profits are by no means great. There are pits in other parts, but they are not many, or much wrought.

Against the apprehension of pits of this nature being exhausted or worn out in these places, it is contended that more than treble the present quantity is capable of being raised from the works already carried on, and that this increased quantity might be supplied for several hundred years to come.

The works and quantities of coals contained in the counties of Stafford, Derby, and Nottingham, are likewise very great, and mostly of good kinds; pits of them being carried on in many places to vast extent.

Cheshire, too, is a coal district, in which a great variety of works for raising it are established in different parts, and much of it, which is of a very good quality, gotten up. The strata of coal here in many cases are several feet in thickness; about Wirrall the seam is five or six feet thick, and the works extensive under the channel of the Dee. In some works the beds of coal lie at the depth of from seventy to one hundred yards below the surface of the ground, and are of different thicknesses to ten feet or more.

In Lancashire, coal of good sorts is most abundant. The beds of it run across the county in somewhat three different parts, as towards the south, nearly in the middle, and on the north-east part. Those in the two first are of considerable breadths and thicknesses in different parts, but the third is much less broad and very thin in many places. They all run, in some degree, from the north-east to the south-west, constantly keeping somewhat the same direction, though occasionally branching out in a lateral manner to some extent. The works on each of these different lines of coal strata, especially the two most towards the south, are very numerous, and, in different instances, of very considerable extent. There are some also established on the northern line, but they are of a far more limited nature. The layers or strata of the coals are of various widths, from a few yards to a very great distance, and their depths or thicknesses from a few inches to six or seven feet. They lie at very different depths from the surface of the earth, according to circumstances and situation; on the eastern side of the county they sometimes nearly appear on the top of the ground, while in the middle, and towards the south-west, they are often a considerable number of yards deep. All about most of the large towns in the southern parts of the district very extensive works are established, where immense quantities of coals are raised for home use, as well as being sent coastways, and, in some cases, for exportation. They are a sort of material which is of vast importance to

the manufacturing state of the county, and which contributes greatly to its prosperity. The quantity is so great, when considered as a whole, that they would seem to be almost inexhaustible.

The cannel coal, which is a sort that has some resemblance to fine black marble, is principally found and raised in the tract about Haigh, near Wigan, which is not more than a few miles square. It lies in pretty thick strata, at the depth of from five to seven or eight yards from the surface. It is of a very fine, hard, inflammable quality, being got up by sharp picks, often with considerable labour, and for which there is much demand, for domestic use, in the neighbourhood.

Coals also abound in the neighbouring counties of Cumberland and Northumberland, being found in many parts of the eastern mountains, and, with not many exceptions, all along the tract, which extends in different degrees of breadth, from Sebergham to Whitehaven, and along the coast to Maryport, forming and comprehending a district of about one hundred square miles, in the former. And they are met with in great plenty throughout the greatest part of the latter county, particularly in the lower district of it; being of the best quality, and the most numerous, and thickest seams, in the south-east quarter; whence those vast quantities are exported which supply the great consumption of the London market, as well as the coasting and foreign trade. A trade which is the foundation of the commerce of the country, and the principal source of its wealth, as well as a never failing nursery for some of the best seamen of the British navy. The former county has likewise works which supply prodigious quantities, both for home consumption and the coastways and export trade. Cannel coal is also raised in this district in pretty large supplies in the neighbourhoods of Caldbeck and Bolton.

Large portions of this article are likewise raised from the works in the county of Durham, which in some parts are carried on with much spirit and enterprise.

Coals are found, and raised in full supplies, in many places, in most of the counties of Scotland, so far as Perthshire; but they have not been met with any farther towards the north in any sufficient quantities. Where they exist, to any extent, in these situations, they are generally of good kinds, and capable of being got up without any great difficulty, seldom lying at any very great depth below the surface.

It has been contended by some, that the coals in the pits and other places, in this country, are inexhaustible, while others maintain the contrary to be the case; as the matter relates to the county of Northumberland, we have the following calculations, on the authority of the writers of the Agricultural Report of that district. And they may perhaps equally apply to others. It is supposed, that towards elucidating this point, it may be of some use to estimate what number of acres are wrought yearly in the county to supply the necessary consumption. In order to accomplish this object, the thickness and number of workable seams of coal must be first ascertained; for which purpose they have been favoured with sections, exhibiting the thickness and depth of the various strata, in some of the deepest pits in the county, one of which has a depth of two hundred and seven yards, with sixteen seams of coals; the other a depth of two hundred and forty yards, with fifteen seams; consequently, if the medium be taken betwixt the two, it will be nearly six yards thick of workable coal; from which may be formed, it is thought, a calculation of the quantity of coal in an acre of ground, supposing the aggregate thickness of the various seams amount to six yards.

An acre of ground contains - 4840 square yards,
 which, multiplied by the thickness 6 yards,
 gives - 29040 cubic yards in
 From which deduct 3d for waste and
 the parts or pillars necessary to be } 9680
 left in working

there remains 19360 cubic yards to
 be wrought.

And as three cubic yards of coal, when wrought, afford
 a Newcastle chaldron, therefore
 $19360 = \text{gives } 6453 \text{ Newcastle chal-}$
 drons per acre,

divided by 3

The coals exported yearly from the rivers Tyne and
 Wear, with Hartley and Blyth, amount to about 825,000
 chaldrons, which, with the home-consumption of the two
 counties of Northumberland and Durham, will make the
 quantity of coals raised yearly about 1,000,000 chaldrons.

And the chaldrons } 1,000,000 = gives 155 acres nearly
 raised yearly } per year, cleared of
 divided by the chal- } 6453 coal six yards thick.
 drons per acre }

And by estimating the breadth occupied by the caking
 coals to be on the average eight miles broad, and twenty-five
 miles long in the two counties, it is found that there will be
 about two hundred square miles, or 128,000 acres of coal
 proper for exportation.

From Newcastle 510,000 chaldrons.
 — Sunderland 315,000 ditto.

In all 825,000
 Then the whole area 128,000 = 825 years. The time
 divided by the } before this space will
 yearly consump- } 155 be wrought out.
 tion }

It is, however, suggested, that there are some reasons to
 suppose that a thickness of seam equal to six yards will not
 be obtained all over an extent of two hundred square miles,
 probably not more, on an average, than four yards; in
 which case the coal will be exhausted in five hundred and
 fifty years. And if the aggregate thickness of the seams
 to be obtained should prove only three yards, then little
 more than four hundred will be the term of continuance;
 but it is probable, it is thought, that before the half of
 that time be elapsed, the price to the consumer will be con-
 siderably increased from the increased expence of obtaining
 them, and the increased length of carriage from the pits to
 the rivers; this last, it is presumed, may be reduced in some
 situations, by adopting canals instead of waggon-ways,
 which, it has often been wondered at, have never yet been
 attempted. From this investigation, it is suggested, that
 the apprehensions of exhaustion are not so chimerical as they
 have been supposed and represented to be by some persons.
 When, however, the vast extent of the working and un-
 wrought tracts, in the different parts of the country, are
 considered, there cannot be any grounds for fear, in this
 respect, for a vast length of time yet to come.

Pits, some what of the quarry kind, are wrought in one
 district of this country, that of Cheshire, for the raising of
 rock salt, in some of which large quantities of this material
 are procured, from different depths, and different thick-
 nesses of the strata of it. In the getting of it different
 means are employed, as those of blasting, picking with im-
 plements, for the purpose of roofing, the using of horses,
 and machinery wrought by steam, for forcing up the sub-

stance, and some others. The digging, raising, and work-
 ing of this article, employs a great number of labourers, and
 it is of much importance to the county in many points of
 view.

But though this sort of material is found in several dif-
 ferent parts of the county, pits, or shafts of it, are at this
 time only wrought in the vicinity of the town of North-
 wich. This arises from a great many different causes, but
 principally from that of the want of water-carriage for the
 conveyance of the material from them. The number of
 pits or shafts, which there are at this time in work, for
 the purpose of raising this article, are about a dozen. They
 are by much the most commonly made in something of the
 square form, being secured on the sides by means of strong
 timber, but they have occasionally a round form, and are
 walled on the sides with bricks.

The beds of this material, that are to be raised, are
 wrought at various depths, the deepest being in general the
 most pure, and they vary equally in their thickness and
 directions, as suggested above. In some cases the beds are
 of the greatest thickness, the more they approach the
 north-east, decreasing in a gradual manner, in their course
 to the south-west; and in some instances they incline from
 north-west to south-east, dipping at the rate of about three
 feet in twenty-seven or thirty.

The strata, which are passed through in getting at and
 working the rock-salt, lie in a very regular manner, and
 consist, in general, of a hard clayey substance and a sort
 of gypseous material in mixture in various ways and pro-
 portions, that of the latter kind being the most predomi-
 nant as the pit or shaft approaches the rocky saline sub-
 stance. In working, the clayey matter is designated by
 the name of *metal* of the several different colours belonging
 to that sort of substance, and the other material by that
 of *plaster*. These strata are mostly of a solid compact
 nature, but occasionally broken in particular places, when
 the metal is termed *baggy* by the workmen.

In the business of working the pits, and raising the rock-
 salt, the rocky beds are reduced into pieces of proper sizes
 for the purpose, by means of blowing them with gun-
 powder, and those of splitting and dividing them with ham-
 mers and proper wedges for such uses; a good secure head-
 way or roofing being constantly provided in the first place,
 to the opening from which the salt-rock is to be taken,
 which is effected by the use of small sharp picks, carrying
 on the work in a plain simple chambering manner.

The workings are sunk from these chamberings to dif-
 ferent depths, as the nature of the beds of rock, and the
 quantity of the purer kind of rock-salt, or Prussian rock,
 as the workmen term it, may direct; but commonly about
 fifteen feet. Occasionally the roofs or headways of the
 pits or shafts are supported by considerable square pillars
 disposed in a somewhat regular manner, but in other cases
 they are wrought out in a sort of long openings, accord-
 ing as the workmen are inclined.

In getting the rock-salt, the workmen are paid by the
 ton at the rate usually of about two shillings, they finding
 the gunpowder and other tools.

In raising the salt from the pits or shafts, horses were
 formerly entirely made use of, but within these few years,
 recourse has been had to the improved steam-engine, as
 already noticed, though it is not yet generally employed at
 every pit. See ROCK-SALT, ROCK-SALT Pits, SALT, and
 SALT Brine Springs.

It is evident from the above account, that in whatever
 way they are considered, the quarries of different kinds
 in this country are of very material importance to its

prosperity and convenience; contributing largely to the carrying on of different sorts of works and improvements. Without them much useful labour must be wholly at a stand; a variety of necessary businesses be incapable of being carried on; and the effects of it upon various arts and manufactures, be much too serious to be thought upon. In short, the numerous substances of different kinds, which are taken from the bowels of the earth in this country, constitute one great source of our national wealth and prosperity.

QUARRIES, Pits, &c. Draining of, the proper, most convenient, and appropriate means of rendering all such sorts of works dry, free from water, and in a fit state to be wrought with ease and advantage. In the effectual performance of all kinds of undertakings of this nature, there is occasion for the application of the same principles, which are spoken of and explained in considering the nature of draining land in general, and the particular manner which is necessary to be pursued in the practice of spring draining. See *DRAINING of Land*, and *SPRING-Draining*.

There can be no doubt, indeed, but that the having recourse to such principles, and the modes of practice resulting from them, will be equally expeditious, beneficial, and successful, as well as in many situations of very material importance, in the various cases of this sort, as in those which have been mentioned; by leading to and introducing the most ready and easy means of diminishing the quantities of water, which are frequently met with in the course of working them, and which not unfrequently obstruct and hinder in a very high degree, but sometimes wholly put a stop to the work which is carrying on in them. Such, at least, is very often the case in quarries of the free-stone, lime-stone, flag-stone, marble, and other kinds, as well as in pits of the coal and other sorts. The want of this sort of knowledge, of course, is one great cause why such a number of quarries and works of that kind, in different parts, often lie altogether, or for a great length of time, in an unwrought state; which might otherwise be wrought to very great advantage.

As it is now well understood, that most springs and subterraneous collections of water are formed and supplied from such grounds or lands as lie higher than that of the places where they are found or met with, which, on account of their being of an open or porous nature, admit that of rain and other sorts of moisture to filtrate and pass freely through them, which sinking and descending to very great depths, through such open materials of the rocky, sandy, gravelly, and other loose qualities, before it becomes impeded and obstructed by some sort of impenetrable stratum or layer of an earthy or solid stony nature, such for instance as those of pure stiff clay or compact rock; it may happen, that in many such cases, in sinking pits or shafts for stone, coal, or any other kind of subterraneous material near the bottoms of hills or high grounds, beds of quicksand will be met with, and dug into, which are so full of water, that to pass through them becomes a most troublesome, difficult, and expensive piece of work, and sometimes impossible to be performed, but which, from knowing that the water proceeds from the porous ground that lies above, it may often be practicable to intercept and cut off the greater part of the water, before it reaches such sand beds in the quarries, pits, and shafts, by the means of boring into and tapping the water at the *tail* of the banks of this nature, provided that the ground naturally declines lower than the place where the sand is found in the quarries, pits, &c., and the whole or most of the water be drawn off, and diverted from them at a comparatively

trifling expence to that which is employed as the common remedy in such cases and circumstances.

In order to accomplish this intention, it will be necessary, in ascending from the quarry or pit, to carefully examine and ascertain, if at any place higher on the declivity, any porous stratum, bed of rock, sand, or gravel, *tails* out, which may conduct and convey the water contained in it to the sand bed, which is below in the works; and where any such bed is found, to cut or bore into it in such a manner as to form a drain, that is capable of carrying away the whole or the greatest part of the water, and of course to clear, or diminish the quantity contained in the quarry or pit, which would otherwise have continued to descend through such porous substrata or beds, and have continued to fill the sands, or quarries and pits.

But although this part of the business may have been accomplished, and the supply of water from the higher ground entirely cut off, a sufficient quantity to injure, hinder, and inconvenience the working of the quarries or pits, may yet continue to drain and ooze from the sides of the sand beds, notwithstanding they should happen to *dip* towards the lower ground, in which cases, however, that water may readily and with great ease be commonly drawn off at some particular point in it.

In order to effect this, and thereby remove the inconvenience of this filtrating water, in descending from the quarries or pits along the declivity, it should be endeavoured to discover and ascertain, at what particular point or place in the low ground, the sand terminates or *tails* out, which is mostly best accomplished by means of proper levelling; and if there should be there any appearance of the waters having a natural outlet, it may, by means of making in it a deep drain, be far more readily and effectually drawn off and removed; as springs, for the most part, naturally pass and flow through narrow, winding, convoluted openings, or perforations; of course, whenever the orifices or passages are opened, enlarged, or made lower than before, the discharge of water becomes greater and more expeditious. Where, however, there happens to be a deep imperious layer or covering of clay, or other matter of a similar nature, placed above or upon the termination or tail of the sand, the drain need only be cut down to it or a little way into it, as by means of boring through it, or the remaining portion of it, a ready and easy outlet or passage may be given to the whole of the water, that may be contained in the sand-bed or other porous stratum.

This mode of draining quarries and pits may often be of great utility, advantage, and convenience, as it will also, in a great degree, remove, or at any rate relieve, the trouble and difficulty that would afterwards have attended the sinking the quarry, pit, or shaft; as the water thus drawn or cut off, must of necessity diminish and reduce the quantity, which would have been found at a greater depth, the same body of it probably passing downwards from one stratum to another, as far as they continue to be porous, or capable of admitting it. Therefore, it is of very material importance to drain and lay dry all such ground as is situated higher, but contiguous to quarries, pits, or other deep subterraneous works of the same kind, for the above stated reasons. And it may, in general, be accomplished with but little trouble, difficulty, or expence, by adopting the same principles, and the same means.

But in regard to the removal of the water found and contained in the bottoms of such quarries, pits, or deep works, it must be drained off and got rid of in quite a different manner, as the level of the ground may probably be, or decline, nowhere lower than the mouths or openings of such quarries,

pits, &c.; as it is solely and particularly on the supposition, and in such cases as where the direction of the different strata and sand-beds have a *dipping* position with the natural inclination of the surface of the land, or lie nearly horizontally, that the method of proceeding which is stated above is practicable, or capable of being employed with any sort of advantage. But should they, for instance, lie in a reverse or contrary direction, there is but little possibility or chance of accomplishing the object, the removal of the water, unless by discovering or hitting on their terminations, somewhere on the opposite sides of the hills or elevations, which in some cases may very nearly or exactly be found out, by ascertaining the precise inclination or direction of the materials of the quarries, pits, &c. and by a careful and exact use of the level. But this will be much better comprehended, and a more clear, full, and perfect notion of its nature be afforded, by the section figure in the plate on draining quarries, pits, &c. in agriculture, as given by Mr. Elkington, in his work on that subject.

This is the manner which is to be pursued in preventing the effects of water, or cutting off that which is met with in sinking the quarries, pits, shafts, or other similar works, before reaching or arriving at the stone, coal, or other sort of material that may be wanted; but that which is found in the bottoms of these different kinds of undertakings, or which proceeds from the rocks or their sides, or in other ways, in the course of working them, is commonly got quit of by means of some sort of machinery, as that of the engine or other kind of pump, in order to assist in working of which, the water gained by cutting the drains already noticed may be particularly useful, especially where the usual stream for that purpose is insufficient in saving the great expence of working such machinery by the power of steam. But without the aid of a natural stream, which is capable of being converted to this purpose, it is rarely possible to find, by means of drains, or in any other way, a quantity of water sufficient to drive such weighty machinery, in a situation of proper height, to have the full and necessary command of it. However, in many cases it may be an acquisition of great utility and value. It is explained at *fig. 2.* in the same plate.

In some situations, where a full and proper command of water can be had, and where the entrance to the quarry, pit, shaft, &c. is also suitable for the purpose, the use to which it may be converted and applied is still more important and advantageous, as the driving of machinery for bringing out the various kinds of materials, and at the same time working an engine-pump, in order to clear the works of the subterraneous water which flows from the cavities of the rocks, which are met with in working these sorts of pits, &c.

It has been remarked in Mr. Elkington's work on draining, in these cases, that the duke of Buccleugh's coal-works, near Langholm, in the county of Dumfries, afford a striking example of this, as well as of the superior powers of water and machinery, when properly combined, where a command of the former can be had, and when the latter is constructed on proper principles, and conducted with that care and ingenuity which are requisite in such difficult undertakings.

In working quarries of lime-stone, free-stone, and other sorts of materials, it not unfrequently happens, that, at a certain depth, part of the rock or other body, which contains the water, is hit upon, by which they are soon so filled with it, as completely to put a stop to the work proceeding any deeper, where the best and often the greatest part of the stone is situated. In all such cases, the most usual remedies have been, either the erection of a wind-mill pump, to draw out part of the water, as the whole cannot be taken away by such means, or the opening of a new quarry or pit

contiguous to the other, which at the same depth mostly meets with a similar obstruction, or the bringing up of a very deep cut, often at great expence, under the level of the water, from the nearest declivity or hollow that can be met with. However, by the following method, all quarries of lime-stone, free-stone, marble, or other materials of the same nature, which are liable to such sort of obstruction, may be completely and effectually cleared of the water at but little expence; while, at the same time, the drain which is made may serve the double purpose of that, and the laying of the wet ground, caused by the spring contained in the rock, which is found contiguous to it, dry.

There commonly lies, immediately under the rock, a bed of strong, stiff, retentive clay, which upholds all the water received and retained by that rocky stratum, and which being, at the same time, bound round on each side by a covering of the same sort of clayey material, or other stiff earthy substance, is not able to discharge itself, and of course constantly remains or stands full in the rock, so as to prevent the working or taking out the stone from the bottom.

In such cases it is necessary, in the first place, to endeavour to find to what side the rock *dips* or inclines, which, in general, may easily be ascertained by the appearance of the surface, in examining the surrounding ground, and the aid of a proper level. When this has been discovered and fully ascertained, a suitable drain must be cut through the clayey covering to the rock, by which the water will be drawn off, which, for want of a proper outlet, formerly stood pent up in the hollows and cavities of the stony stratum or body. This is further and more fully explained by *figs. 3 and 4*, in the same plate.

But, in some cases, this sort of evil or inconvenience may be removed and remedied in a different way. As it frequently happens that a bed or body of the same stone, which has a close, compact nature or quality, is found lying under one which has a more open porous texture, with fissures and cracks in it, that are admissible of water, which obstructs and keeps up the water in the upper bed or layer, in such a manner, that not any of it can pass or filtrate through it to an inferior, or still deeper open stratum or bed; and on sinking or cutting through this compact bed of stone, another layer is met with, which is of so open and porous a nature, as to admit the reception of any water from the above one, which may come upon it.

And sometimes a bed of gravel or sand is found under that of the close stone, which being still more capable of absorbing or taking up any water that may be let down to it, is far better and more properly suited for the purpose of clearing the upper bed of stone from water, than a stratum of open stone itself.

Therefore, when this is discovered and ascertained to be the case, and the water is *kept up* by the second bed of stone, so as to be injurious and hurtful to the working of the upper bed, and which will be equally so in working the second; the work may be greatly freed and relieved by boring through the close bed of stone, and letting down the water into the more porous one below, or into a stratum or body of dry sand or gravel, should there be such a one underneath it. But in place of boring, the sinking of small pits through the close stone is a more effectual method of letting down the water, though a much more difficult one in the execution.

The methods of digging and boring, even in the bottoms of quarries, pits, and shafts, where pumps and other machinery of the same nature are made use of, as has been noticed above, may, in some cases, not only be practicable, but advantageous for letting down the water which they contain into an inferior open stratum.

That of boring has been practised with complete success in the case of a colliery in the county of York, which had been wrought many years, and in which the water was raised about sixty yards by a steam-engine: the proprietors of which, on boring down from the bottom of the pit next to the engine-pit, to the further depth of about ten yards, in order to ascertain the depth or thickness of a seam of coals, which was supposed to lie below those then wrought; the workmen, on taking out the boring rods, found that the water from the works, which usually ran across the bottom of this pit to the engine-pump, now ran down the holes they had made. And that the steam-engine pump, on being set to work, contained little or no water, it having escaped through these holes, and continued to run through the same ever afterwards, rendering the pump useless. It is remarked, that this instance of water at so great a depth from the surface, finding a passage at a further depth of ten yards, or less, and immediately below, is extremely singular and striking in its nature. The situation was much higher than the nearest contiguous vallies, or the level of the sea. Trials of this sort can seldom be made, therefore the cases are rare, uncommon, and curious. But in extensive tracts of level land, where lakes or morasses have been formed, and which cannot be laid dry by cutting open drains, or driving levels through rocks, except at an expence for which the lands, when drained, would never compensate, the above instances warrant the trial of experiments with boring rods, which, if not attended with success, can be made at little expence.

In the county of Lancaster, about the town of Ormskirk, as well as in some other parts, stone quarries are cleared of water exactly in the manner which has been already pointed out, but which *fig. 5.* in the plate will explain much better.

The success of the practice has likewise been farther shewn by the late T. Eccleston, esq. of Scarrisbrick-hall, an ingenious and extensive proprietor of land in the same neighbourhood, who remarks, that in stone quarries thereabouts, wells or pits are occasionally sunk to the open bed, which have proved serviceable. This mode was practised in a stone delf near the above town in a very beneficial manner. But in order to lay the delf more effectually dry to a greater depth, Mr. Elkington, on viewing the surrounding ground, marked out where he thought the rock terminated, or tailed out, and at the lowest level set out a drain to be cut and carried up to the rock, part of which work has been executed, and a very considerable flow of water comes from it; but on account of its great depth, sixteen feet, the whole will not be finished before he has seen the work again. The drain he has thus laid out is about ten feet lower than the bottom of the stone quarry, and when completed, will lay the head or body of stone dry lower than the present floor. All rocks, for the most part, where they terminate, are succeeded by broken loose stones of the same nature as the rock, and they are frequently, nay almost always, succeeded by sand, which, when in a thick bed, and of a running nature, such as quicksand, often cause great expence in cutting through to the tail end of any rock. This is more fully explained in speaking of the manner of draining in hilly lands, and where the soils are of a mixed nature. See *Spring-Draining*.

Therefore, in all such cases as this, where there is any danger of meeting a quicksand, boring or sinking pits through the bed of close stone, is by much the most advisable, and at the same time the least expensive method that can be pursued.

The situations of marle pits are for the most part such, that they require very extensive cuts to be made through

some parts of the surrounding banks or sides of them, in order to carry or convey off the superabundant quantity of water which prevents their being dug or wrought to advantage. This business might frequently be effected in a much less troublesome and expensive manner, by the method of letting the water down by means of fishing pits or openings through the retaining and upholding stratum underneath the bed of marle, into some absorbent porous body of materials lying still deeper, which is capable of receiving it. Where the space of ground that is occupied by the marle is of considerable size, several pits will be required, in order to effectually carry off the water; and where it is necessary that they should be so deep as to be in danger of falling in, they ought to be walled round the sides, or filled up to near the top with loose stones, through which the water can settle and find its way. And any such cross drains or cuts as may be necessary for the purpose of collecting the water must be so formed and conducted as to lead into the pits. But in many cases the water may be removed and got rid of in a still more easy manner, especially where the situation of the ground is favourable and suited to the purpose. In instances where the surrounding banks decline or fall on the opposite sides *lower than the water*, by cutting drains into them, and boring with an horizontal auger into the tails of the strata containing the water, it may be drawn off and brought down to a level lower than that of the bed or body of marle. And as this water is not unfrequently supplied by a spring which rises in some part of the higher ground, and descends into the place where the marle is found, it will be necessary, in all such cases, to cut off the source of it, and divert the flow of water into some other channel; as by that means the quantity of water below will be lessened, and more easily and readily carried off by the pits or drains which may have been formed.

Mines and shafts, for the purpose of raising different sorts of metals, are often much impeded, or wholly prevented from being wrought by the water which is brought into them from a distance, by various kinds of mineral strata. In many such cases, the water flowing in this way may be intercepted, by making cuts up to the lowest banks of them, from some neighbouring water-course, or other convenient outlet, and then boring or digging pits in the bottoms of such cuts, when the metals to such depths or levels will be rendered free from water, and capable of being wrought. This will, however, be more amply shewn in considering the manner of draining, in some cases of wetness, caused by springs arising in this way. See *Spring-Draining*.

In removing the water, or freeing the bottoms of quarries and pits from it, where machinery is required, the writer of the work on "Landed Property" has remarked, that in cases where *shaft-drains* are found to be impracticable, *well-drains* and pumps become necessary, and are the most proper; as they may be wrought by water, where streams can be conducted to them; or by wind in high exposed situations; or in works of consequence, where fuel is moderately cheap, by small steam-engines. However, in instances where large bodies of water are required to be raised and discharged at the height of a few feet only, marsh-mills, such as are made use of in low marsh-land districts, are found the readiest and most useful kind of machinery for the purpose.

In some cases of this nature, the bottoms of quarries, pits, and mines, may be cleared from water, simply by forming openings into them from some parts of the neighbouring ground where it falls lower than the levels of them, at sufficiently short distances, without any other more expensive works being undertaken for the purpose. This should always be fully considered before any means are resorted to

for laying them dry, as it may occasionally be the saving of much labour, trouble, and money.

QUARRY, in *Glaziery*, a pane, or piece of glass, cut in a lozenge, or diamond-form.

The word seems formed by corruption, from *quarrel*, (which see); unless we will suppose it to come immediately from the French *quarre*, *square*.

Quarries, or quarrels of glass, are of two kinds; viz. square and long, each of which is of different sizes, expressed by the number of pieces which make a foot of glass; viz. 8ths, 10ths, 12ths, 15ths, 18ths, and 20ths; but all the sizes are cut to the same angle, the acute angle being 77° 19' in the square quarries, and 67° 22' in the long ones.

QUARRY, in *Falconry*, is the game, or fowl, which the hawk is in pursuit of, or has killed.

QUARRY, among *Hunters*, is sometimes used for part of the viscera of the beast taken; given by way of reward to the hounds.

QUARRY-Cart, a name commonly given to that sort of cart which is principally employed in the work of quarries, and which is generally of a low, compact, strong kind, in its nature, form, and manner of construction, in order to sustain heavy weights, and receive them without difficulty, or the danger of being destroyed. Carts for this purpose should always be made of well-seasoned wood, be well put together, and have sufficient strength of timber in those parts where the main strefs of the load is placed. See CART.

Some quarry counties have well-formed carts of this nature, as many of those towards the northern boundaries of the kingdom.

QUARRY-Waggon, or *Truck*, a small carriage of the low truck kind, which is much employed in the business of quarries, especially those of the slate kinds, for the purpose of holding and conveying the rough materials, which have been blown from the large massy rocks, or separated in other ways, out of or from the quarries and pits in which they are situated and contained, to the places where they are to receive their different preparations and shapes.

It is formed and constructed on a frame somewhat similar to that of the common barrow, and mounted on two low light iron wheels on the fore part, having two feet behind, projecting from the frame, bent something in the manner of the letter S, and of sufficient length to let it stand or rest in a horizontal position while it is in the act of being loaded. These feet are usually made of iron, but they may be formed of other materials. A sort of inclined plain is formed from the bottoms of the quarries or pits, up which it is forced, with great ease and facility, by the workmen, or small animals of the horse kind, after being filled with these sorts of heavy materials. It is a very useful and convenient machine in this application, being met with in most of the slate quarries in the northern part of Lancashire, as well as in those of many other districts of the kingdom.

QUARRYING, the business of directing and conducting the nature and management of sinking the different kinds of quarries, pits, and shafts, as well as of the different sorts of work which are necessary to be undertaken, carried on, and performed, in the several different descriptions of them; such as those of separating, getting up, and preparing the various sorts of materials for use in the arts, or in other ways. It is a practice which requires considerable knowledge and experience, to be fully master of it in all its different bearings and intentions. See QUARRY, and QUARRYING *Slates and Stones*.

Almost every sort of quarrying-work requires a different kind of management, not only in the opening and sinking

the quarries and pits in the grounds at first, but afterwards in the methods and practices of working them, and getting up the various sorts of materials from them, as well as in the modes of preparing, trimming, and arranging them, after they have been raised. They are, however, mostly well known and familiar to the quarry-men and pit-men who are usually engaged in works of the several different kinds.

QUARRYING *Slates and Stones*, the methods of preparing and fitting them for their different uses and applications at the quarries and pits where they have been raised. The former of these articles, particularly those of the blue, green, and purple or blackish kinds, undergo several different sorts of preparation in the quarrying, according to the purposes to which they are to be afterwards applied. They are separated and divided into very thin pieces or slates, where light, neat coverings are required, or in much demand; but for more strong and heavy coverings, in exposed situations, or other places, they are split into much thicker sheets, layers, or slates, and are, of course, more clumsy in their appearance.

Each sort in the business of quarrying is wrought in a separate manner, and packed up by itself; the different sorts having appropriate names, as has been already seen.

The white or brown slates are never divided and prepared in so fine a way as the other kinds, but separated into much thicker flakes or laminæ, in this intention. The blue, green, and purple or darkish sorts, are, for the most part, found capable of being split into very thin laminæ or sheets; but those of the white, or brownish free-stone kinds, can seldom be separated or divided in any very thin manner, as the layers of the large masses of the stones are of a much thicker nature, they consequently form heavy, strong, thick coverings, proper for buildings in exposed climates and situations, and of the more rough kinds, such as barns, stables, and other sorts of out-houses.

In the different operations and processes of this sort of quarrying, slate knives, axes, bars, and wedges are chiefly made use of in the different intentions of splitting and cleaning the slates, they being separated into proper thicknesses by the axe, bar, and wedge, and afterwards clipped into their proper forms and shapes by the knife. All the different inequalities which may appear upon any part of them, are likewise removed by this last sort of implement.

In the quarrying of the latter sorts of materials, or those of stones, the work is usually performed in such a manner as to suit the different uses for which they are intended. Where flags are to be formed, they are split or riven into suitable thicknesses, and squared to different sizes, so as to be adapted to different applications. These operations are executed in rather a rough way, as they are afterwards to be finished by the stone-mason. When for steps, they have the proper breadths and depths given to them in a sort of squaring manner, being left to be completed as they may be wanted for particular uses and applications. Gate-posts are, for the most part, quarried so as to have from about a foot to a foot and a half or more in the square. Trough-stones have the quarrying performed so as to be formed into various proper-sized squares or other forms, in a rough manner, being left in these states to be afterwards hewn and hollowed out, in the intended parts, by the stone-masons.

Stones for building purposes are usually raised and quarried out roughly into something of the square shape, being left in that state for the builders, who afterwards fit them so as to suit their own purposes and intentions.

In the quarrying of stones, the quarrymen commonly make use of large hammers, with cutting ends on one side, the other being formed in a plain manner; strong, sharp, crow-

bars, and broad, sharp, iron wedges; by which means these matters are, from the constant practice of the men, split and torn into such forms as are wanted with great ease and facility. See QUARRY.

QUARRYING Tools, the different sorts of implements which are employed or made use of in the different works of this kind, as in the raising and preparing the various sorts of materials of this nature. They are principally such as those which have been noticed already, and different descriptions of picks, mattocks, and jumpers, or boring implements, for the purpose of blasting the various kinds of stone, and other hard materials. These tools are individually described under their particular heads. See each of them.

QUARRY

QUARRYINGS, the small pieces which are broken or chipped off from the different sorts of materials which are found and wrought in quarries, while they are undergoing their different preparations for various uses. These substances, where they are of the hard kind, such as those of the blue and lime-stone, as well as some other sorts, are extremely well calculated for the purpose of forming and repairing roads, as they are nearly, if not quite, in a state fit for immediate application in this way. Materials of these kinds ought, therefore, where they can be conveniently had, never to be neglected by those who have the care and management of roads, as they will save much expence and trouble, in a great number of instances. See ROADS.

Quartation

QUARTATION, in *Metallurgy*, is the separation of silver from gold by means of aqua fortis or nitric acid; which is an operation that has something singular in it.

If silver and gold are mixed together into a mass, and the gold is not less than one-third part of the mass in weight, the best aqua fortis poured upon it is not at all capable of dissolving the silver; but if you add more silver to this mass, by melting it again in the fire, with such a necessary addition of that metal alone as should bring the gold in the mass to the proportion of less than one-third of the whole, and suffer it to cool, then aqua fortis poured on it will corrode the silver from it: this is also by so much the more strongly performed, as the quantity of gold is less than in the proportion of one-third of the whole mass; but experience has taught us, that aqua fortis dissolves silver mixed with gold quickly enough when the gold constitutes but one, and the silver three parts of a mixed mass of them; and in this case, if the solution is not too impetuously performed, the gold usually remains in such a proportion, in the same figure that the whole mass had before the separation of the silver by this menstruum; so that, in this case, there is no reason to apprehend the gold's being torn into minute particles, and dissipated in some measure; though this can hardly be pre-

vented when the silver exceeds the three-quarter proportion, in regard to the gold in the mass. The artificers, therefore, always make it their study to observe very exactly this proportion of the gold being one-fourth part of the mixture; and thence it is that the operation itself has been called quartation.

In order to ascertain nearly the proportion of gold and silver in a mass, the assayers rub this mass upon a touchstone, so as to leave a mark upon it; and they then make marks upon the stone with some of those needles, called touch-needles, the colour of which they think comes nearest to that of the mass: by comparing the marks of these needles with the mark of the mass, they discover nearly the proportion of the gold and silver in the mass. The mass of gold and silver to be quartered ought previously to be granulated, by melting it in a crucible, and pouring it into a large vessel full of cold water, while at the same time a rapid circular motion is given to the water by quickly stirring it round with a stick or broom. The vessels generally used for this operation are called parting-glasses. The aqua fortis must be purified for this purpose, and should be so strong as to be capable of acting sensibly on silver when cold, but not so strong as to act violently. If it be very strong, and the vessels

well closed, a small quantity of the gold will be dissolved along with the silver, which is to be guarded against. Little heat ought to be applied at the beginning, the liquor being apt to swell and rise over the vessel; but when the acid is nearly saturated, the heat may be safely increased. When the solution ceases, which may be known by the discontinuance of the effervescence, or emission of air-bubbles, the liquor is to be poured off. If any grains appear entire, more aqua fortis must be added, that all the silver may be dissolved. If the operation has been performed slowly, the remaining gold will have still the form of distinct masses, which are to receive solidity and colour by putting them into a test under a muffle, and making them red-hot. If the operation has been performed hastily, the gold will have the appearance of a black mud or powder, which after five or six washings with pure water, must be melted. The silver is usually recovered by precipitating it from the aqua fortis by means of copper vessels, into which the liquor is poured, or of plates of copper, which are thrown along with the liquor into glass vessels. A considerable heat is required to accelerate this precipitation. Dr. Lewis observes, that when the aqua fortis has been per-

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fectly saturated with silver, no precipitation is occasioned by plates of copper, till a drop or two of aqua fortis is added to the liquor, and then the precipitation begins, and continues as usual. The precipitated silver must be well washed in boiling water, and fused with some nitre, the use of which is to scorify any cupreous particles which may adhere to the silver.

Here we may add, that silver and gold may be parted from one another by the vitriolic acid, as effectually, though not so commodiously, as by the nitrous. If the compound be reduced into grains or thin plates, and boiled in about twice its weight of oil of vitriol to dryness, the silver will be so far corroded, as to be easily washed off by a little more of the acid: or if the mass, after the corrosion, be melted in a crucible, the gold will separate and subside, the silver forming a scoria above it. Gold may be purified in the same manner from several other metallic bodies. M. Scheffer says, that this is the most direct way of separating tin from gold. Lewis's Com. Phil. Techn. 95. 149, &c. See ASSAYING, DEPART, and GOLD.

Quick lime

Quick Lime, in *Rural Economy*, such lime as is in the caustic or most active state, and which possesses the greatest power of operating upon different substances with which it may come in contact. It is quite the opposite in its qualities and properties, to that which has fallen down into a powdery state, in consequence of being saturated with water and carbonic acid gas, or fixed air, or which is slaked and become effete. Its powers, when applied upon land in this condition, have already been noticed in speaking of lime. See **LIME**.

But it possesses qualities and properties in the way of a cement, the utility of which for building, for various domestic purposes, properly belong to this place. According to Dr. Anderson, lime is in the best and most fit state for this use when the most perfectly caustic, or in the most crystallizing condition. It is remarked, that the powder of lime, when reduced by means of water into a thin or fluid sort of paste-like form, and then suffered to become dry, concretes into a coherent mass, which fixes to stones and other rough bodies in a very firm manner, and in this way becomes a proper cement for building any sort of walls. And that, after this pasty material has once become firmly dry, it is quite indissoluble in water, and incapable of ever being softened again by the moisture of the atmosphere or other similar causes. Hence it excels many other sorts of cements.

When composed for the purpose of building walls, &c. it is usually denominated *mortar*; but when formed as an application in the way of a smooth coating upon any plain surface without intermixture with stony matters, it is commonly here termed *plaster*.

When made from the lime of the purer sort of **lime-stone**, it is found to be more soft and crumbly, and to acquire a less degree of hardness, and to be broken with much less force, than where the lime-stone from which it is made contains a large proportion of sand, in which case it becomes much more hard, firm, and durable.

It has, however, been discovered that the purest lime may be rendered a firm cement by adding a proper proportion of clean hard sand to it; hence the practice of blending sand with lime, when intended for mortar, has become so universal. This is fully shewn to have been very early the case, by the oldest lime-built walls which are now to be met with.

It nevertheless still remains a desideratum to ascertain the due proportion of sand which is necessary, as both writers and practical masons greatly disagree in opinion on this matter, as well in their directions about the mode of mixing the materials, as of applying the cement; some of the more modern, especially, ascribing extraordinary effects to a small variation in these particulars, while others deny that these circumstances have any sensible effect on the durability and firmness of the cement.

It is conceived that these different and contradictory opinions arise from an imperfect knowledge of the nature of quick-lime, and the variations it may admit of; for these variations are so very great, as to render it impossible to afford

any general rules that can possibly apply in all cases. It is, therefore, conceived to behove those who are desirous of acquiring any consistent and satisfactory knowledge on this head, to endeavour to ascertain, in the first place, the circumstances which render calcareous substances *at all* capable of becoming a cement, and then to trace the several changes that may be produced upon it by other extraneous causes.

Having explained the circumstances which cause the differences in lime-stone, and pointed out the different constituent principles of it, as well as various other peculiarities; it is stated that lime, which has in any way absorbed its full quantity of air from the atmosphere and become mild, is altogether unfit for becoming a cement, and that, of course, it is evident, that a great change may be produced upon the quality of any lime, by having allowed less or more of it to be in this state before it is worked up into mortar. And further, that if a large quantity of water be put to fresh slaked quick-lime, and beat up with it into a thin sort of paste, the water dissolves a small portion of the lime, which as it gradually absorbs its air, is converted into crystals; between the particles of which crystals, that part of the lime which was not dissolved, and the other extraneous matters which may have been mixed with it, are entangled, so as to form a firm coherent mass of the whole. And that the pasty substance formed in this manner, is the well-known article mortar; and this heterogeneous, imperfectly semi-crystallized mass, constitutes the common cement employed in building ordinary walls or other erections. These circumstances, therefore, being known, it is thought that it will not be difficult to comprehend what are the particulars that are necessary to form the most perfect cement of this nature. That since lime becomes a cement only in consequence of a certain degree of crystallization taking place in the whole mass, it is sufficiently obvious that the firmness and perfection of that cement must depend upon the perfection of the crystals; and the hardness of the matters that are entangled among them; for if the crystals are ever so perfect and hard of themselves, if they be separated from one another by any brittle incoherent medium, it is evident that the whole mass must remain in some degree brittle and incoherent. That as water can only dissolve a very small proportion of lime, even when in its most perfect saline or caustic state, or while it remains deprived of its carbonic acid gas, and as happens in other similar cases, no more of the lime can be reduced to a crystalline mass than has been actually dissolved in the water; it happens of course, that if mortar be made of pure lime and water alone, a very small proportion only can be dissolved by that small quantity of water that is added to it; and as this small proportion alone can afterwards be crystallized, all the remaining undissolved particles of the lime will be entangled among the few crystals that are formed. And as the undissolved lime in this mass will in time absorb its air, and be converted into *mild* calcareous earth without having had a sufficiency of water to allow it to crystallize, it must concrete into a friable mass exactly resembling chalk; it follows, that this kind of mor-

tar, when as dry as it can be made, and in its highest degree of perfection, will always be soft, and easily crumbled into powder.

But that, if, instead of forming the mortar of pure lime alone, a large proportion of sand be added to it, the water will in this case dissolve as much of the lime as in the former; and the particles of hard sand, like sticks or threads, when making sugar-candy or other crystals, while surrounded by the watery solution, will help to forward the crystallization, and render it more perfect than it otherwise would have been, so as firmly to cement the particles of sand to one another. And as the granules of sand are perfectly hard of themselves, so as not to admit of being broken down like the particles of chalk, it necessarily follows, that the cement made of these materials must be much more perfect in every respect than the former.

After considering a variety of circumstances in regard to the solubility of lime in water, and its crystallization, it is remarked, that when a large quantity of sand is mixed in the mortar, that sand will of course bear a great proportion to the whole mass; so that the water that may be mixed with the mortar will be much greater in proportion to the quantity of lime contained in this mortar, than if the whole had consisted of pure calcareous matter. And that, as the sand absorbs none of that water,—that water, now pure, is at liberty to act once more upon those few particles of caustic lime that may still remain in the mortar, which will be dissolved and converted into crystals in their turn. In this way it may happen, in some circumstances, that a very large proportion of the lime may become crystallized; so that the mortar will consist almost entirely of sand enveloped in crystalline matter, and become in due time as hard as stone itself; whereas mortar, consisting of pure lime, without sand, can hardly ever be much harder than chalk. It is not, however, to be supposed, that in any case this dried mortar will assume that transparent crystalline form, or the compact firmness of some sorts of calcareous matters, such as marble and lime-stone. In mortar, in spite of the utmost care that can ever be taken, a very considerable quantity of the lime must remain undissolved; which undissolved lime, although it may be so much separated by the sand and crystalline lime-stone as not much to affect the hardness of the mortar, yet it must still retain its white chalk-like appearance. As marble and lime-stone are, however, always formed by those particles of lime that have been wholly dissolved in water, and from which they have been gradually separated by a more slow and more perfect mode of crystallization, they have nothing of that opaque calx-like appearance, but assume other colours, and appear more firm, uniform, and compact; the sand and other matters that may be enveloped in them being entirely surrounded with a pure crystalline matter.

But to obtain the most perfect kind of mortar, it is not, however, enough that a large proportion of sand should be employed, and that the sand should be intimately mixed with the lime; it is also of the utmost importance that a large proportion of water be added; for without this it is impossible that a large proportion of the lime can be crystallized: and the mortar, in that case, would consist only of a mixture of chalky matter and sand, which could hardly be made to unite at all, and would be little more coherent than sand by itself, and less so than pure chalk. In that case, pure lime alone must afford rather a firmer cement than lime with sand. It is also of very great importance that the water be retained as long in the mortar as possible: for if it be suddenly evaporated, it will not only be prevented from acting a second time upon the lime, after

a part of what was first dissolved has been crystallized, but even the few crystals that would be formed when the water was suddenly evaporating, would be of themselves much more imperfect than they otherwise most certainly would have been. In proof of which, instances of the crystallization of common salt, lump sugar, and sugar-candy, are adduced; after which it is noticed, that every one knows what a difference there is between the firmness of the different substances; and that as great must be the difference between the firmness of that cement which has been slowly dried, and that which has been hastily hardened by the powerful action of a warm air.

It is contended, that it is owing to this circumstance that the lime, which remains all winter in a mortar tub filled with water, is always found to be much firmer and more coherent than the mortar that was taken from the same tub and used in any work of masonry, although in this case the materials were exactly the same. From the same cause, any work cemented with lime under water, if it has been allowed to remain undisturbed and uninjured until it has once become hard, is always much firmer than that which is above the surface of the water.

In order to render the force of the above reasoning more strong and convincing, lime cement or mortar is compared to a mass of matter consisting of a congeries of stones closely compacted together, and united by a strong cementing matter that had, while in a fluid state, pervaded all the interstices between the stones, and afterwards become a solid indissoluble substance. If the cementing matter be exceedingly hard and coherent, and if the stones bedded among it be also very hard and firm, the whole mass will become like a solid rock, without fissures, that can hardly be broken to pieces by the power of man. But, although the cement should be equally firm, if the stone, of which it consists, be of a soft and friable nature, suppose chalk or sand-stone, the whole mass will never be capable of attaining such a degree of firmness as in the former case; for when any force is applied to break it in pieces, although the cement should keep its hold, the solid matter cemented by it would give way, and the whole would be easily broken to pieces. Whereas in mortar, the sand that is added to it represents the stones of a solid matter in the composition, the particles of which are united together by the lime which had been formerly dissolved, and now crystallized, which becomes an exceedingly solid and indissoluble concretion. And as the particles of sand are of themselves exceedingly hard, and the cement by which they are united equally so, it is plain that the whole concretion must be extremely firm, so as to require very great force to disunite any particle of it from the whole mass. But if, instead of employing sand, the only solid body that is entangled among the cementing matter should be chalk, (as in all cases where the mortar consists of pure lime alone,) or any other slightly cohering substance, let the cementing particles of that composition be ever so perfect, it is impossible that the whole can ever attain a great degree of firmness, as these chalky matters will be easily broken asunder.

It is remarked, in addition, that a variety of conjectures have been made about the nature of the lime cement employed by the ancients. It has been thought that they possessed an art of making mortar, which has been long since entirely lost; as the cement in the walls which have been built by them, appears to be, in many cases, much firmer than that which had been made in modern times. Yet, when the mortar of these old buildings is analysed, it is found to consist of the same materials, and nearly in the same proportions, in which they are now made use of.

And it is thought probable, that their only secret consisted in mixing the materials more perfectly than the rapidity or avarice of modern builders will permit, in employing their mortar in a much more fluid state than is done now, and in allowing it to dry more slowly, which the immoderate thickness of many of their walls would naturally produce, without any preconcerted design on their part. Tradition has even handed down to the present times the memory of the most essential of these particulars; as the lower class of people, in every part of the nation, at this moment invariably suppose and believe that these old walls were composed of a mortar so very thin, as to admit of its being poured, like a fluid, between the stones, after they were laid in the wall: and the appearance of these old walls, when taken down, seems to favour this popular tradition. Nor is it doubted but that this may have been the case. The stones in the outer part of the wall, it is thought, were probably bedded in mortar nearly as is practised at present; and the heart, after being packed well with irregular stones, might have the interstices between them entirely filled up with fluid mortar, which would insinuate itself into every cranny, and in time adhere as firmly as the stones themselves, or even more so, if the stones were of a sandy friable nature. And that, as these walls were usually of very great thickness, it might often happen, that the water in this mortar, by acting successively upon different particles of caustic lime, would at length be entirely absorbed by successive crystallizations, so as to become perfectly dry, without any evaporation at all; in which case, a very large proportion of the original lime must have been regularly crystallized in a slow and tolerably perfect manner, so as to attain a firmness little inferior to lime stone or marble itself.

It is supposed that, upon these principles it is easy to account for the superior hardness of some old cements, when compared with that of modern times, in which a practice very different is usually followed, without having recourse to any wonderful *arcana* whatever.

Monsieur Lorient, a late French writer, imagined that he had made a perfect discovery of the way in which the ancients employed their quick-lime, so as to obtain such an extraordinary firm cement; from which discovery, he conceived, very important benefits might be derived to society. According to his opinion, the ancient cement consisted of lime and sand nearly in the same proportions as are commonly employed for that purpose at present. But instead of making it of slaked lime entirely, as is done now, he contends that they employed a certain proportion of their lime *unslaked*, which they mixed with their mortar immediately before it was used. And it is further noticed, that this newly discovered cement dries and hardens almost under the hand of the operator, without cracks or flaws of any sort; that it neither expands nor contracts with the air;—that it is impervious to moisture, and may not only be employed for making roofs of houses that are subjected to the continual dropping of water, basins, aqueducts, canals, &c. which will instantly contain water in any quantities but even finer works of the pottery kind; that it perfectly resists frosts, and has a variety of other interesting qualities. The trials of Dr. Anderson with the same sort of materials do not, however, confirm the great certainty and utility of this discovery. “That such effects as the writer describes,” says the doctor, “will invariably be produced, merely by adding a certain proportion of unslaked lime in powder to mortar, or even by making the mortar entirely with powdered quick-lime, I may without hesitation venture to deny, not only from the reasoning that has been given, but from

actual experiment, again and again repeated by myself; and which is likewise, in some measure, corroborated by the experience of Mr. Dossie.”

On these accounts, it is supposed, that if Monsieur Lorient, has really experienced these uncommon effects from the mortar he has tried, it must have been occasioned by some other unobserved peculiarity, and not merely by the circumstance to which he seems to ascribe it. Possibly the doctor supposes the lime he employed may have been impregnated with a gypsum, or the sulphate of lime, as is probable, for many reasons. The effects and qualities of which, as to becoming a fine powder, and of suddenly setting, are well known, but it never acquires the stony hardness that lime cement is sometimes endowed with, although it takes the smoothest polish of any cement we know: on which account, it has long been employed as a plaster where fine ornaments are required.

There are unquestionably, however, many doubtful and mysterious circumstances connected with this matter, which require the aid of further trials and experience in their full explanation.

There are still further a few other circumstances that may influence the quality of common lime-mortar. If lime-stone be sufficiently calcined, it is deprived of all its moisture, and of all its carbonic acid gas, or fixed air. But experience shews, that lime-stone will fall to powder on the effusion of water upon it, when it is much less perfectly calcined, and while it still retains almost the whole of its fixed air. And that as masons have hardly any other rule for judging whether lime-stone be sufficiently calcined, except this single circumstance of its falling to a powder when water is poured upon it, it may thus easily be perceived, that the same lime may be more or less fitted for making good mortar, according to a circumstance that, in a great measure, eludes the observation of operative masons; for if it should happen that all the pieces of lime drawn from a kiln at one time, were just sufficiently calcined to make it fall to a powder with water and no more, that powder would be altogether unfit for making mortar of any kind. This is a case that can seldom happen: but as there are a great many intermediate degrees between that state and perfect calcination, it must often happen that the stone will approach nearer to one of these extremes at one time than at another; so that the mortar may be much more perfect at one time than at another, owing to a variation in this particular.

All those who have written on the subject of lime as a cement, have endeavoured to ascertain what is the due proportion of sand for making the most perfect cement. But a little attention to the matter will shew, that all rules, which could be prescribed as to this particular, must be so vague and uncertain, as to be of little utility to the practical mason; as, besides the variation which may arise from a more or less perfect degree of calcination as above, it is a certain fact, that some kinds of lime-stones are much more pure, and contain a much smaller proportion of sand than others do; some being found almost perfectly pure, while others contain eleven-twelfths of sand and all the intermediate proportions of it. Therefore it would be absurd to say that pure lime would require as small a proportion of sand when made into mortar, as that which originally contained in itself a much larger proportion of sand than any writer has ever ventured to propose for being put into mortar.

Besides, there are differences caused by the different nature of the calcination in the different sorts of lime-stone, from which it may, upon the whole, be concluded, that

about one-tenth of pure lime-stone is not enough calcined to admit of being made into mortar; and that of the most impure sorts of lime-stone, not above one-fourth part of the lime contained in it is so much calcined as to be in a caustic state.

The variation that is produced by these means in regard to the proportion of sand that will be required to the lime in the one or the other case, is found to be so extremely great as hardly to be conceived. It is, however, stated, that the best mortar that has been seen made, was formed of lime which had been found to contain eleven parts of sand to one of lime: to this there was added between twice and thrice its whole bulk of sand by measure; which may be allowed to have been at least three times its quantity *by weight*. Therefore, supposing that every particle of that lime had been so perfectly calcined as to be in a caustic state, there could not be less than forty-seven parts of sand to one of lime. As much may, however, be allowed for the uncaustic part of the lime as is pleased, and the calculation made accordingly. But it is hardly possible to suppose that above one-hundredth part of this mass, independent of the water, consisted of pure caustic calcareous earth.

On these considerations it is conceived, that it is impossible to prescribe any determinate proportion of sand to lime, as that must vary according to the nature of the lime and other incidental circumstances, which would form an infinity of exceptions to any general rule. But it would seem that it might be safely inferred that the moderns in general rather err in giving too little sand, than in giving too much. It deserves, however, to be noticed, that the sand, when naturally in the lime-stone, is more intimately blended with the lime than can possibly be ever effected by any mechanical operation; so that it would be in vain to hope to make good mortar artificially from pure lime, with such a small proportion of caustic calcareous matter as may sometimes be effected when the lime naturally contains a very large proportion of sand. But there seems to be no doubt, that if a much larger proportion of sand were employed, and if that were more carefully blended and expeditiously worked than is common, the mortar would be much more perfect than is usual in modern times, as has been proved by actual trials.

Another circumstance that tends greatly to vary the quality of cement, and to make a greater or smaller proportion of sand necessary, is the mode of preparing lime before it is beaten up to mortar. When for plaster, it is of great importance to have every particle of the lime-stone flaked before it is worked up; for, as smoothness of the surface is the most material point, if any particles of lime should be beaten up in it, and employed in work before sufficiently fallen, the water, still continuing to act on them after it was worked up, would infallibly flake such particles, which forcibly expanding themselves, would produce those excrescences on the surface of the plaster commonly termed blisters. Consequently, in order to obtain a perfect kind of plaster that will remain smooth on the surface and free of blisters, there is an absolute necessity to allow the lime to lie for a considerable time macerating or *soaking* in water, before it is worked up. And the same sort of process is necessary for the lime when intended for use as mortar, though not so absolutely. Great care is, however, required in the management in this respect; the principal things being the getting of well-burnt lime, and the allowing it to macerate or *soak* with the water for only a *very short time* before it is used; but that which is the best burnt will require the maceration of some days in the water before it is sufficiently flaked in the whole

mass for this purpose. See *SOURING Lime for Mortar and Plaster*.

It has been almost universally admitted, that the hardest lime-stone affords a lime that will consolidate into the firmest cement; and hence generally concluded, that lime made of chalk, produces a much weaker cement than what is made of marble or lime-stone. It would seem, however, that if ever this be the case, it is only incidentally, and not necessarily so. As from the nature of calcareous matter, every kind of lime is equally fit for becoming a firm cement, if it be first reduced to a proper degree of causticity, and has afterwards a due proportion of sand properly mixed with it, before it be employed in work. Different sorts of lime, without doubt, differ much from each other in the proportion of sand they naturally contain, and, of course, require very different proportions of sand to be added to them before they can be made equally perfect as a cement; which is an economical consideration, of no small moment in some cases, as it may make one sort of lime a great deal cheaper than another on some occasions, and, of course, deserves the attention of builders in general. See *LIME*.

The excellencies and defects of other substances that may be occasionally mixed with lime in making cement may be just noticed. Those commonly used as an addition to mortar, besides sand of various denominations, are powdered sand stone, brick-dust, and sea-shells. And for forming plaster, where closeness rather than hardness is required, they are lime that has been flaked and kept long in a dry place, till it has become nearly effete, powdered chalk or whiting, and gypsum in various proportions; besides hair and other materials of that nature. But some others have been more lately advised, such as earthy balls, slightly burnt and pounded, powdered and sifted old mortar rubbish, and others of a similar kind. All of which substances are found objectionable in some respect or other for this use, sand being the only perfectly suitable material that can be easily met with; on which account it has been always justly preferred. Pure firm crystallized sand is the best, but all pure sands are not equally proper in this intention. See these substances respectively. See also *CEMENT* and *SAND*.

It is stated by sir Humphry Davy, in his work on "Agricultural Chemistry," that there are two modes in which lime acts as a cement; in its combination with water, and in its combination with carbonic acid. When quick-lime is rapidly made into a paste with water, it soon loses its softness, and the water and the lime form together a solid coherent mass, which consists of seventeen parts of water, to fifty-five parts of lime. When this hydrate of lime, while it is consolidating, is mixed with red oxyd of iron, alumina, or silica, the mixture becomes harder and more coherent than when lime alone is used; and it appears that this is owing to a certain degree of chemical attraction between hydrate of lime and these bodies; and they render it less liable to decompose by the action of the carbonic acid in the air, and less soluble in water. It is thought that the basis of all cements that are used for works which are to be covered with water must be formed from hydrate of lime; and that the lime made from impure lime-stones answers this purpose very well. Puzzolana, it is said, is composed principally of silica, alumina, and oxyd of iron; and it is used mixed with lime, to form cements intended to be employed under water. It is stated that Mr. Smeaton, in the construction of the Eddystone lighthouse, used a cement composed of equal parts, by weight, of flaked lime and puzzolana. Puzzolana, it is said, is a decomposed lava. Terras, which was formerly imported in considerable quantities from Holland, is found

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to be a mere decomposed basalt : two parts of flaked lime and one part of tarras form the principal part of the mortar used in the great dykes of Holland. It is supposed that substances which will answer all the ends of puzzolana and tarras, are abundant in the British islands. An excellent red tarras may be procured in any quantities from the Giant's Causeway, in the north of Ireland : and decomposing basalt is abundant in many parts of Scotland, and in the northern districts of England in which coal is found.

It is observed that Parker's cement, and cements of the same kind made at the alum-works of lords Dundas and Mulgrave, are mixtures of calcined, ferruginous, siliceous and aluminous matter, with hydrate of lime.

It is noticed, that the cements which act by combining with carbonic acid, or the common mortars, are made by mixing together flaked lime and sand. These mortars at first solidify as hydrates, and are slowly converted into carbonate of lime by the action of the carbonic acid of the air. It was found by Mr. Tennant, that a mortar of this kind, in three years and a quarter, had regained sixty-three *per cent.* of the quantity of carbonic acid gas, which constitutes the definite proportion in carbonate of lime. The hardness of the mortar in very old buildings is also thought to depend upon the perfect conversion of all its parts into carbonate of lime. The purest lime-stones are the best adapted, it is said, for making this kind of mortar. The magnesian lime-stones make excellent water cements, but act with too little energy upon carbonic acid gas to make good common mortar. The Romans, on Pliny's authority, made their best mortar a year before it was used ; so that it was partially combined with carbonic acid gas before it was employed, it is supposed.

It is likewise suggested, in regard to the cultivation and improvement of land by means of this material, that quick-lime in its pure state, whether in powder, or dissolved in water, is injurious to plants ; grasses in several instances having been killed by watering it with lime-water : but that lime, in its state of combination with carbonic acid, is an useful ingredient in soils. Calcareous earth is found in the ashes of the greater number of plants ; and exposed to the air, lime cannot long continue caustic, but soon becomes united to carbonic acid. That lime, when combined with about one-third of its weight of water, constitutes hydrate of lime ; and that it becomes carbonate of lime by long exposure to the atmosphere, the place of the water being supplied by carbonic acid gas. On mixing freshly burnt or flaked lime with any moist fibrous vegetable matter, a strong action occurs between them, and they form a sort of compost, part of which is commonly soluble in water. In this way, lime renders matter, before comparatively inert, nourishing ; and from charcoal and oxygen, abounding in vegetable matter, it becomes converted into carbonate of lime at the same time. Mild lime, or powdered calcareous substances, have no action in this way on vegetable matter ; by their operation they prevent the too quick decomposition of bodies previously

dissolved, but do not tend to form soluble matters. Consequently it is clear that the operation of quick-lime and mild calcareous substances, depend upon wholly different principles. The former, on being applied to land, tends to bring the hard vegetable matter contained in it into more rapid decomposition and solution, as a proper food for plants. The latter only improve the texture of it, or its relation to absorption : it is merely an earthy ingredient. Quick-lime, in becoming mild, has a similar action, but while taking on that state, prepares soluble out of insoluble matter. On this depends the operation of lime in the preparation for wheat crops, its efficacy in fertilizing peats, and in bringing into cultivation all sorts abounding in hard roots, dry fibres, or inert vegetable matter. The question, of course, whether quick-lime should be applied to land or not, depends on the quantity of inert vegetable matter it contains ; and that whether mild lime, marl, or powdered lime-stone, should be used or not, on the quantity of calcareous matter already in the land. All sorts of land are improved by mild lime, and ultimately by quick-lime, which do not effervesce with acids ; and the sandy sorts more than the clayey kinds. In land deficient in calcareous matter, but containing much *soluble* vegetable manure, the use of quick-lime should constantly be avoided, as tending either to decompose the soluble matters, by uniting to their carbon and oxygen in becoming mild, or to combine with the soluble matters, and form compounds with less attraction for water than the pure vegetable substance. The same is the case in regard to most animal manures ; but its operation is different in different cases, according to the nature of the animal matter. On the whole, it should however never be employed with animal manures, except when too rich, or for preventing noxious effluvia. It is hurtful in mixture with common dung, and tends to produce insolubility in the extractive matter. It is useful in mixture with simple vegetable barks, &c.

The solution of the question about the inutility and disadvantage of magnesian lime, which has lately been found useful in small quantities on the poorer lands in Leicestershire, as from twenty-five to thirty bushels the acre, and in larger ones, on the rich soils ; it is supposed to depend upon that sort of lime having a less attraction for carbonic acid than the other, in consequence of the portion of that substance in it, and thereby remaining longer in the caustic state ; and its becoming sooner a carbonate of lime in the rich than in the poor soils. Magnesia, while in the caustic state, is poisonous to certain kinds of plants, and acts so in the mixture as lime. It may be usefully applied in large quantities to peat-earths ; and to lands injured by too much of this sort of lime, peat-earth will be a proper and effectual remedy, when used in a suitable proportion.

More full information may be met with on this curious and interesting subject in the first volume of Anderson's *Essays on Agriculture and Rural Affairs*, in Dossie's *Memoirs of Agriculture*, vol. ii. and in Sir Humphry Davy's *"Agricultural Chemistry."*

Railway

RAILWAY, *Tram or Dram-road, or Waggon-way*, in *Rural Economy*, a track constructed of iron, stone, timber, or other material, upon the level surface of an inclined plane, or other situation, for the purpose of diminishing friction, and thus serving for the easy conveyance of heavy loads of any kind of articles. See *Plate IV. Canals, figs. 31 to 35.* See also **CANAL**.

It has been remarked, that railways have hitherto been confined, almost exclusively, to coal-works, and other mines; and that inventions, whose only recommendations are simplicity and usefulness, are often suffered to lie long in a state of public neglect; while others, perhaps, of no real utility, but of more imposing aspect, and being pertinaciously blazoned forth by interested or blinded partisans, are readily adopted; and bask, for a while, in the sunshine of public favour. The time has, however, at length arrived, when carriages moving on level surfaces, or on gently inclining planes, with little friction, and *without* obstructions, are fast spreading over the face of the country. It has been observed that there may be many lime-works, as well as other sorts, from which railways may be laid, in different directions, with great benefit to their proprietors and the surrounding neighbourhoods in general.

With the view of diminishing horse labour, it has been suggested by Dr. Anderson, in his *Recreations in Agriculture*, that where internal canals cannot be established, this may be effected, and intercourse facilitated, by means of railways, which have not yet been introduced into general practice. It is further stated, that they were first solely employed for transporting coals to a moderate distance from the pits, to the places where they could be shipped, being universally made of wood. And long, says he, had they been applied to this use, without any idea having been entertained that they could be employed for more general purposes. By degrees they were, however, carried to a farther extent; the scarcity of wood, and the expence of their repairs, suggested the idea of employing iron for the purpose of improving these roads. At the first, flat rods of bar-iron were nailed upon the original wooden rails, or as they were technically called, *sleepers*; and this, though an expensive process, was found to be a great improvement. But the wood on which these rested being liable to rot and give way, some imperfect attempts were made to make them of cast iron, but these were found to be liable to many objections, until the business was taken in hand by Mr. Outram, engineer, at Butterly Hall, Derbyshire, who contrived at the same time, so far to diminish the expence, and improve the strength of the road, as to bring them to a degree of perfection, that no one who has not seen them can easily conceive could have been done. And it is added, that this having been carried into execution in a few cases, and found to answer, has been improved upon and simplified by practice, till it is now brought to such a state of perfection as to have given proofs, that it admits of being carried much beyond the limits of what was for many years conceived to be possible, and to afford demonstrative evidence, that it may be in future employed to a wider extent still, to which no limits can be at present assigned or foreseen.

There are a great number of railways in Derbyshire, Shropshire, Lancashire, and many other parts of the country.

In the first of the above counties, there are railways of very different lengths; one of five miles in length, leading from the town of Derby to the collieries in the vicinity; another, from the lime-stone rocks on the Cranford canal, called the Crick railway, which is about one mile and a half

in length; a third from the Beggarlee colliery to the same canal, denominated Barber and Walker's railway, of similar length; a fourth from the lime-works in the neighbourhood of Bolton, to the canal near Whaley bridge, termed the Peak-forest railway, which is about six miles in length; a fifth called the Marple railway, of about one mile and a half long, on the Peak-forest canal; sixthly, railways over Blisworth-hill near Nottingham, on the Grand Junction canal, which are three miles and a half in length, and constructed in a double manner; a seventh, which has the name of the Ashby de la Zouch railway, has four miles of double and eight miles of single rails. Some of these railways are formed in a very complete manner, especially those which have been made since the various improvements of them were introduced. They have been of prodigious utility and advantage to the county, both in regard to its agricultural improvements and its manufacturing interests and concerns.

These sorts of railway roads have likewise been introduced into many parts of the county of Salop, with vast benefit and success to the different interests of the district. They have here had a new application, in being employed for the purpose of conveying heavy weights from different levels on canals.

Speaking of the great utility of canals in the carriage of various articles in this county, it is observed by Mr. Telford, an able engineer, that another mode of conveyance has frequently been adopted to a considerable extent; which is that of forming roads by means of iron rails laid along them, upon which materials are carried in waggons, which contain from six to thirty hundred weight; experience, he thinks, has now convinced us, that in countries the surfaces of which are rugged, or where it is difficult to obtain water for lockage, where the weight of the articles of the produce is great in comparison with their bulk, and where they are mostly to be conveyed from a higher to a lower level, that in those cases, iron railways are in general preferable to canal navigation.

It is supposed, that on a railway well constructed, and laid with a declivity of fifty-five feet in a mile, one horse will readily take down waggons containing from twelve to fifteen tons, and bring back the same waggons with four tons in them. This declivity, therefore, suits well, when the imports are only one-fourth part of what is to be exported. If the empty waggons only are to be brought back, the declivity may be made greater; or an additional horse applied on the returning journey will balance the increase of declivity. If the length of the railway were to be considered, it may, it is supposed, without much inconvenience, be varied from being level to a declivity of one inch in a yard, and by dividing the whole distance into separate stages, and providing the number of horses suitable for each portion of railway, according to the distance and degree of declivity, the whole operation may be carried on with regularity and dispatch.

It is upon the whole believed, that this useful contrivance may be varied so as to suit the surface of many difficult countries, at a comparatively moderate expence. It may be constructed in a much more expeditious manner than navigable canals; it may be introduced into many districts where canals are wholly inapplicable; and in case of any change in the working of mines, pits, or manufactories, the rails may be taken up and laid down again in new situations, at no very great expence or trouble.

It is also further noticed, that some parts of this and the neighbouring counties, in which canals had once been

intended to be formed, have since been looked over and examined with the view of having iron railways instead of navigable cuts; and in many cases this may be the most advisable and proper, particularly in all situations where difficulties arise in the constructing of navigable canals, or other sorts of works for water carriage.

The county of Lancaster, too, has a great many of these iron railways for the convenience, accommodation, and advantage of the different collieries, manufactories, and other works, where heavy loads are to be transported. The coal work near St. Helens, in the vicinity of Liverpool, has a double railway some miles in length; and at the iron-works of lord Belcarras, near Wigan, as well as his canal coal pits near the same place, there are double railways of very considerable length. To the south of the town of Preston, at a small distance from Bamber bridge, there is likewise one communicating with the Lancaster and Kendal canal, which is also double and of great length; serving to convey the coals from the southern parts of the county to that canal, in order to their distribution in the northern parts, and the adjoining districts.

On the east side of the same county they also prevail in many places, and are found of the greatest use, being the means of dispatching much business in a ready manner and without much expence of labour.

The utility of these railways has been found to be extremely great in other coal-works and canals, where they are at present very extensively employed; and it has been suggested, that they may be applicable in other cases, as for shortening the team labour of a farm so as to bring it within one day's journey, where more than one were formerly necessary, by which a great saving in labour and expence may be made. Also, in rendering the business of lime works more easy and expeditious in different instances. It has likewise been hinted by Mr. Beaton, in the first volume of Communications to the Board of Agriculture, that they might be had recourse to on roads where there are unavoidable rises or falls, for taking up or letting down heavy loaded waggons or other carriages. It is observed, that near Colebrook Dale there is one at a small distance from the iron bridge, upon which loaded boats are drawn up to a canal, two hundred and twenty feet above the level of the river Severn, and let down in a similar manner into it, by which means twenty-two locks are saved, and the work executed in an expeditious manner. It is supposed, that this is the greatest inclined plane in Europe, or perhaps in the world, for though they are much used in China in the place of locks, he has never heard of any of them being equal in height to this. The rails are best made of iron. It is added, that they have been found useful in improving soft, mossy, boggy lands, on which horses cannot travel; a rail road of this sort having been formed through a peat moss near Manchester by Mr. Wakefield, while it was under improvement, at the expence only of about three hundred pounds a mile, on which a single horse was capable of drawing with the greatest facility seven waggons at once, each being loaded with about seven hundred weight of marle, bearing in the whole forty-nine hundred weight, and with the weight of the waggons upwards of three tons. This was performed, it is observed, over a place where a few months before a dog could hardly venture without the danger of being *swamped*. On the Ketley and other canals in the county of Shropshire, vast advantages have been derived from laying railways upon inclined planes, and letting down and drawing up the different articles by means of machinery, as may be seen in the very able Agricultural Report of that district, where excellent representations of them are given.

Besides these different cases of railways, another has been suggested by the writer of the Annals of Agriculture, which is that of having them laid from the flack-yards to the thrashing machines, by which the grain may be conveyed to them at any time with ease and convenience, as well as any particular flack that may be wanted.

It is further stated by the ingenious Dr. Anderson, that the best idea he can give of the benefit that may result to the community from the use of this kind of railways, will be from stating some facts respecting them, which were lately communicated to the Society of Arts by Mr. Wilkes, of Measham, near Loughborough, in Leicestershire; a spirited and judicious agriculturist. He had a railway of this sort made, which was about five miles in extent, leading from a coal-mine to a market. He found it to fully to answer his expectations after it was finished, that he communicated to the above society an account of some trials he had made of it, requesting that such of the members of that respectable institution as were desirous of information on that head, would do him the honour to witness some experiments that he wished to make upon it, for the information of the public. A committee of the members was accordingly deputed for that purpose, and before them he shewed that a moderate sized horse, of about twenty pounds value, could draw upon it with ease down hill (the descent being one foot in a hundred) thirty-two tons, and without much difficulty forty-three, and seven tons up hill, independent of the carriages. The doctor concludes from these facts, that upon a perfect level a horse could draw with ease from ten to twenty tons. It is observed, that Mr. Wilkes's railway, on which the experiments were made, was, from local circumstances, laid upon wooden sleepers, and is not so perfect as those done upon stone. But it is added, that twenty tons are the load which such a horse could draw with ease, travelling at the usual waggon rate, in boats upon a canal; so that the number of horses required in this way will not be much, if at all, greater than on a canal. Certain advantages attach to this mode of conveyance, which do not so well apply to a canal, and *vice versa*; but it is not his intention to draw a parallel between these two modes of conveyance. Nobody can entertain any doubt, he thinks, about the utility of canals where they are easily practicable. He only wishes to point out this as an eligible mode of conveyance where canals cannot be conveniently adopted.

It is further remarked, that it was customary at the first, to put the whole load to be drawn by one horse upon railways into one waggon; but now, when the load is so much augmented, it has been found eligible to divide it into many parts, so that no one waggon shall carry more than one or two tons; by this method the weight is so divided, that the pressure is never so great upon one point as to be in danger of too much crushing the road; the carriages can be made much more limber and light in all their parts, and they are much more easily moved, and more manageable in all respects than they otherwise would have been. And another advantage of this arrangement, which deserves to be particularly adverted to, is, that it admits of shifting the carriages so as to leave a load, as it were, in parcels at different places where they may be required, without trouble or expence. This, when it comes to be fully understood and carried into practice, will, he thinks, be a convenience of inestimable value, a thing that has been always wanted, and never yet has been found though it has been diligently sought for. The able writer has here endeavoured to illustrate its importance and utility in transporting goods from the wet docks now forming on the Isle of Dogs to London, and in carrying roads to different distant parts of the country; in which

cafés, and in all where there is much business to be done, they would require to be double, one for going, and the other for coming upon, to prevent interruption and interference.

And he afterwards offers a few remarks, tending to shew the practicability of the measure, and to guard against letting out upon a bad plan, which might, he supposes, in time to come, frustrate the good that might have resulted from the undertaking; merely premising, that he proposes these railways solely for the purpose of conveying weighty loads, leaving the roads, as at present, open for coaches and light carriages.

Also with a view to discover how far it may be practicable to introduce these iron railways into general use, he has made some inquiries respecting the expence of making them; and although this must vary according to the abundance and goodness of materials, and other circumstances, the following statement may serve to give some general notions on that head. In the most eligible situation, where materials are abundant and good, and circumstances favourable, the lowest expence at which a single railway of this sort can be made, will be about one thousand pounds a mile. But as a single railway must be liable to great inconveniences, unless under very particular circumstances, double railways ought to be considered as the only useful sort. These, for public purposes, according to the opinion of the inventor, should be very substantially made. The metal used should be of the stoutest sort, and of substance enough, not merely to carry the weights proposed, but to be equal to bear almost any blow or shock that they may be likely to experience; and, thus made, what they will lose by rust or wear, will be long ere it materially weakens them. Made after such a manner, in favourable situations in the country, a double railway may, he thinks, cost about two thousand pounds a mile, but in the neighbourhood of London, where the charge of every thing is high, and where they should be of the strongest sort, we should suppose they might cost nearly three thousand pounds a mile. It is bad economy, he thinks, to save on articles of this sort at the first; for the little expence thus laid out then will save much in repairs: how small these repairs are, may be imagined from this circumstance, that when a road is thus made, the undertaker does not scruple to supply all that are broken, free of charge, for the first three years. Say then that such a road cost three thousand pounds a mile, this would bring a charge upon the turnpike of 150*l.* a-year; say 50*l.* more for annual repairs; this is, in all, 200*l.* *per annum.* Compare this with the expence of keeping the present roads in repair. It has been suggested to him, that there is annually laid out in repairs upon the road from Hyde Park Corner to Hounslow, considerably above one thousand pounds a mile; so that the difference of expence is, even at the beginning, very much in favour of railways: and were the money thus at first expended to be gradually paid off, the tolls might thus be lowered almost to nothing. And, he thinks, that a turnpike road cannot be made in almost any situation for less, as he is told, than 1000*l.* *per mile*; but where it is of considerable width, as near great towns, it will run from 1500*l.* to 2000*l.* *per mile*; and in annual repairs, including the purchase price of materials, carting them on the road, spreading, raking off, and carting away again, from 100*l.* to 1000*l.* a mile. Say 1500*l.* prime cost, the interest is 75*l.* and 150*l.* for repairs, the annual charge of such road will be 225*l.* This is an expence of 100*l.* a-year more than the other. But for the present, let us suppose that they will be equal, the extra charge for purchasing ground for a new waggon-way, &c. being equal to that surplus; let us now see what

would be the difference of charge to the employers of these waggons in the two cases. Supposing the road to be so much employed as that 100 waggons (or loaded carriages to the same amount) pass each day, carrying six tons each, drawn by eight horses; these, at one shilling each waggon for toll (or two-pence a ton), would produce 5*l.* a day, or 1825*l.* a-year; which, at the rate of eight miles for each turnpike, would be 228*l.* *per mile*, the surplus being produced by road horses and light carriages. The charge then to the employer, for this stage, must be 1825*l.* and the keep of 800 horses, besides servants, incidental charges, and owner's profits for the transporting of 600 tons of goods a day. Say that the same horses travel two stages a day, the turnpike money would be doubled; that is, 3650*l.* *per annum*; the keep of 800 horses, at 2*s.* each *per diem*, is 29,200*l.* These sums added make 32,850*l.*; owner's profit and incidental charges, say 10 *per cent.*, 3285*l.*; in all 36,135*l.*, or, on 219,000 tons (being 600 tons a day), about one-fourth *per ton.* And supposing the same quantity of goods carried on the railway, and the same turnpike money paid, and that each horse drew only fifteen tons, this would require only, he thinks, forty horses; the keep of which, at 2*s.* a day, would be 1460*l.*, add the toll, 1825*l.* is 3285*l.* *per annum.* Owner's profit, &c. upon this sum 10 *per cent.* as above, 328*l.*; in all 3613*l.*, or about four-pence a ton, just one-tenth part of the charge in the other case. He thinks, that when the object comes to be considered in this point of view, few measures that can be proposed will hold forth such an important national improvement as this would be. Considered with regard to the consumption of the produce of the earth (an object at present deserving the fullest attention, as this improvement can be applied to almost every part of the country), it would, he supposes, reduce the number of heavy road horses to one-eighth part of what they are at present, and of course augment the number of cattle or other consumable provisions in a proportionate degree, so as greatly to lower the price of the necessaries of life. It would, in the next place, lower the price of the carriage of goods of all kinds to an amazing extent; and lastly, as a consequence of that, it would give such encouragement to agriculture, as no other measure that can be contrived could ever effect, and that without costing one shilling expence to any one individual, or to the state. On the contrary, by inducing cheapness of provision, and affording such efficacious encouragement to manufactures and to agriculture, it would produce a general prosperity, which, by augmenting the consumption of taxable commodities, would augment the public revenue; while, at the same time, every individual would feel himself relieved from the pressure of many taxes that prove distressful to him at present. After justly reprobating every sort of gambling speculations by monied men in undertakings of this nature, and shewing the numerous evils that attend them, he advises it, as highly necessary to prevent these railways from ever becoming private property, on any account, to keep them open and patent alike, to all who shall choose to employ them as a king's highway, under such regulations as it shall be found necessary to subject them to by law. In short, they should, he thinks, be put upon the same footing, in all respects, as public roads are at present, only under the direction of a distinct set of commissioners, who should have the superintendence of every thing that concerns this species of roads only. These commissioners should be vested with authority under an act of parliament, to erect turnpikes upon them, to levy certain stipulated tolls, and to mortgage the produce of these tolls for the purpose of raising money to be applied in the necessary purchases of land, and making the roads. In the act it

should be expressly stipulated, that the produce of these tolls should be applied solely to keeping the road in repair, paying the interest of sums borrowed, and clearing off the principal as fast as the collections would admit; and when the whole money borrowed was thus paid off, the tolls should be so lowered as only to produce money sufficient to keep the roads in a state of continually good repair. Thus would the expence of transporting goods be annually diminishing, and the prosperity of the country be thereby augmenting from day to day. He adds, that he is particularly earnest in this business, as he has not been an unconcerned observer of the effects that have resulted from the establishment of turnpike roads in Scotland, which were begun within his recollection; and these effects have been such as no man who had not seen it would have believed could ever have taken place. Distance may be said to be thus diminished from place to place; lands that were originally far beyond the influence of the town as a market for any thing else than live-stock, are thus brought, as it were, close to its gates; and the value of the produce of many articles is thus to them augmented fourfold, while they are at the same time diminished to the public. Not only is the value of produce raised, but the quantity also of that produce is augmented exceedingly by means of manures which become then accessible. Fossile manures, such as chalk, lime, and marle, which were formerly confined to a narrow spot, expand themselves as if it were by a magical power, and by that expandible influence diffuse around fertility, riches, and plenty. Coals and other weighty articles that may be useful in arts or manufactures of various kinds, which never were, nor ever could have been of any value to the owners of them, so long as the expence of transportation exceeded a certain sum, find a ready market to any extent as soon as the price falls below that rate, thus contributing not only towards the enriching of the owners, but to the furnishing of employment to the various persons who must be engaged in preparing or transporting them to market, and the universal accommodation of the whole. Around every market you may suppose a number of concentric circles drawn, within each of which certain articles become marketable which were not so before, and thus become the source of wealth and prosperity to many individuals. Diminish the expence of carriage but one farthing, and you widen the circle; you form, as it were, a new creation, not only of stones, and earth, and trees, and plants, but of metals, and what is more, of industry, of happiness, and joy. It is added, that by making these roads the property of the public, and free to every person to bring his own waggons upon them wherever he pleased, farmers, when near them, would make bye roads of the same sort leading into these from their respective parishes; the inhabitants of villages and country districts would join together, and at one common expence make roads of the same sort leading to a greater distance inwards, as they now make bye roads for themselves. Thus would all be accommodated; those who had business enough to furnish a sufficient load for one horse might go to market with it when they pleased; those who had dealings on a smaller scale could have one, two, or more waggons of their own conjoined with those of others to make up a load for one horse: and those of still smaller means could have one waggon loaded with the joint articles belonging to two, three, or more. A ton weight might then be pushed before a man to market for many miles, as a wheelbarrow is now. It is scarcely possible, he supposes, to contemplate an institution from which would result a greater quantum of harmony, peace, and comfort, to persons living in the country, than would naturally result from this arrangement. In fact, he knows, he says, no one

measure, that would tend so effectually to lower the price of the necessaries of life, and restore abundance.

In what regards the method of forming and constructing these railways, it is observed by the same writer, that the following has been given by the inventor as the most improved plan: first, that the best line the country affords should be traced out, having regard to the direction of the carriage of articles or trade to be expected; and if such trade be both ways in nearly equal quantities, a line as nearly horizontally level as possible should be chosen. If the trade is all in one direction, as is generally the case between mines and navigation, then the most desirable line is one with a gentle gradual descent, such as shall make it not greater labour for the horses employed to draw the loaded waggons down, than the empty ones back; and this will be found to be the case on a railway descending about one foot vertical in one hundred feet horizontal. Or, if the railway and carriages are of the very best construction, the descent vertical may be to the length horizontal as 1 to 50, where there is little or no upgate loading. In cases between mines and navigations the descents will often be found greater than could be wished. On a railway on the improved plan, where the descent is more than as 1 to 50, six or eight waggons, loaded with thirty or forty hundred weight each, will have such a tendency to run downwards, as would require great labour of one horse to check and regulate, unless that tendency was checked by sledgeing some of the wheels. On such, and sleeper roads, iron flippers are applied, one or more to a gang of waggons, as occasion may require. Each flipper being chained to the side of one of the waggons, and being put under the wheel, forms a sledge. Where the descent is very great, steep inclined planes with machinery, may, it is observed, be adopted, so as to render the other parts of the railway easy. On such inclined planes the descending loaded waggons being applied to slide the ascending empty, or partly loaded ones, the necessity of sledgeing the wheels is avoided; and the labour of the horse greatly reduced and lessened.

In order to obtain the desired levels, gentle descents, or steep inclined planes, and to avoid sharp turns, and circuitous tracks, it will often be found prudent to cross valleys by bridges and embankments; to cut through ridges of land; and in very rugged countries short tunnels may, he thinks, sometimes be necessary. The line of railway being fixed, and the plans and sections by which the same is to be executed and settled, the ground for the whole must be formed and effectually drained. The breadth of the bed for a single railway, should be, in general, four yards; and for a double one six yards, exclusive of the fences, side drains, and ramparts.

That the bed of road being so formed to the proper inclination, and the embankments and works thereof made firm, the surface must be covered with a bed of stones broken small, or good gravel, six inches in thickness or depth. On this bed must be laid the sleepers, or blocks to fasten the rails upon. These should be of stone in all places where it can be obtained in blocks of sufficient size. They should be not less than eight, nor more than twelve inches in thickness; and of such breadth (circular, square, or triangular,) as shall make them 150lbs. or 200lbs. weight each. Their shape is not material, so as they have a flat bottom to rest upon, and a small portion of their upper surface level, to form a firm bed for the end of the rails. In the centre of each block should be drilled a hole, an inch and a half diameter, and six inches in depth, to receive an octagonal plug of dry oak, five inches in length; for it should not reach the bottom of the hole; nor should it be larger than so as to put in

easily, and without much driving; for if too tight fitted it might when wet burst the stone. These plugs are each to receive an iron spike or large nail, with a flat point and long head, adapted to fit the counter-sunk notches in the ends of two rails, and thereby to fasten them down in the proper position, or situation in which they are to lie.

With regard to the rails, they should be of the stoutest cast-iron, one yard in length each, formed with a flanch on the inner edge, about two inches and a half high at the ends, and three and a half in the centre; and shaped in the best manner to give strength to the rails, and keep the wheels in their track. The soles of the rails, for general purposes, should not, he thinks, be less than four inches broad; and the thickness proportioned to the work they are intended for. On railways for heavy burdens, great use, and long duration, the rails should be very stout, weighing 40lbs., or, in some cases, nearly half an hundred weight each. For railways of less consequence, less weight of metal will do; but it will not be prudent to use them of less than 30lbs. weight each, in any situation exposed to breakage above ground. But it is observed that in mines, and other works under ground, where very small carriages only can be employed, very light rails are used, forming what are called train roads, on a system introduced by Mr. Carr; and these kinds of light railways have been much used above ground in Shropshire, and other counties where coals and other minerals are obtained.

It is added, that in fixing the blocks and rails great attention is required to make them firm. No earth or soft materials should be used between the blocks and the bed of small stones or gravel, on which the rails must all be fixed by an

iron gage, to keep the sides at a regular distance, or parallel to each other. The best width of road for general purposes is four feet two inches between the flanches of the rails; the wheels of the carriages running in tracks about four feet six inches asunder. Rails of particular forms are necessary where roads branch out from or intersect each other; and where carriage roads cross the railways; and, at turnings of the railways, great care is required to make them perfectly easy. The rails of the side forming the inner part of the curve should be fixed a little lower than the other; and the rails should be set a little under the gage, so as to bring the sides nearer together than in the straight parts: these deviations in level and width to be in proportion to the sharpness of the curve. The blocks and rails being fixed and spiked fast, nothing more remains to be done than to fill the horse-path, or space between the blocks, with good gravel, or other proper materials; a little of which must also be put on the outside of the blocks to keep them in their proper places. This gravel should always be kept below the surface of the rails on which the wheels are to run, to keep the tracks of the wheels free from dirt and obstructions. The form of the rails must be such as will free them from dirt if the gravelling is kept below their level.

And in the constructing of the carriages great attention to avoid friction is necessary, particularly in the formation of the wheels and axles, which must be adapted to the sort of railways and kind of loading; but for which general directions cannot be given in a narrow compass. It is probable that this valuable invention may also be applicable to many other purposes in agriculture or manufactures, as it becomes more fully understood, and the facilities which it affords are better known. See CANAL.

Red

RED, in *Physics*, one of the simple or primary colours of natural bodies, or rather of the rays of light.

The red rays are those which are of all rays the least refrangible: hence, as sir Isaac Newton supposes the different degrees of refrangibility to arise from the different magnitudes of the luminous particles of which the rays consist, the red rays, or red light, is concluded to be that which consists of the largest particles. See COLOUR, LIGHT, and RAY.

Authors distinguish three general kinds of red; one bordering on the blue, as colombine, or dove-colour, purple, and crimson; another bordering on yellow, as flame-colour and orange; and between these extremes is a medium, partaking neither of the one nor the other, which is what we properly call *red*.

Acids generally turn black blue, and violet into red; and red into yellow, and yellow into a very pale yellow.

Alkalies change red into violet, or purple; and yellow into feuilemort, or dead leaf-colour.

Terrestrial and sulphureous matters become red by extreme heat; and some, at length, black, as we see in brick, red bole, red chalk, slate, &c. All these, when vitrified by a burning-glass, become black.

Lobsters become red by a moderate fire; and by a violent one, black. Mercury and sulphur mixed and heated over a moderate fire make a beautiful red, called *artificial cinnabar*.

An acid spirit, as lemon juice, being poured on a blue solution of turcolle, turns it into a beautiful red. Alkali restores it again to its original blue. Filtrating of some reddish wines takes from them all their red colour.

M. De la Hire observes, that a very luminous body viewed through a black one, always appears red; as when the sun is seen shining through a black cloud. He adds, that some people who see all the other colours perfectly well, yet have no idea of red, and only see it as black.

RED, in *Cosmetics*, a fucus or paint with which the ladies enliven their cheeks and lips.

There are two kinds of reds; the one in leaves, called Spanish red; the other a liquor, which is an extract of a scarlet dye.

RED, in *Dyeing*, is one of the five simple or mother colours of the dyers.

Some reckon seven kinds, or casts of red: viz. scarlet-red, crimson-red, madder-red, half-grain-red, half-crimson-red, lively orange-red, and scarlet of cochineal. But they may be all reduced to three, according to the three principal drugs which give the colours; which are kermes, cochineal, and madder.

The fine scarlet, called *scarlet of the Gobelins*, is given with agaric, bran-water, woad, and scarlet grain, or kermes. Some dyers add cochineal, and others fennugreek; brightening it with bran-water, agaric, tartar, and turmeric. See KERMES and SCARLET.

Crimson-red is dyed with bran-water, tartar, and mastiche cochineal. See CRIMSON.

Madder-red is dyed with madder; to which some add realgar, or red arsenic: others, common salt, or other salts, with wheat-flour; or agaric with spirit of wine, with galls or turmeric. See MADDER.

The half-grain is made with agaric and bran-water, half scarlet grain, half madder, and sometimes turmeric.

The half-crimson is made of half madder, half cochineal. As to the lively orange-red, the stuff must be first put in yellow, then in a liquor made of goat's hair, (which has been boiled several times with madder,) dissolved over the fire with certain saline liquors, as urine, tartar, &c.

The scarlet of cochineal, or Dutch scarlet, as the French call it, is made with starch, tartar, and cochineal; after first boiling it with alum, tartar, sal gemma, and aqua fortis in which pewter has been dissolved.

Besides these seven reds, which are good and allowed colours, there is also a Brasil red; which is discouraged, as fading easily.

Of the seven good reds, only four have particular casts, or shades; the madder-red, crimson-red, lively orange-red, and scarlet of cochineal.

The casts or shades of crimson are flesh colour, peach colour, carnation rose colour, and apple-tree flower colour. Those of madder are flesh colour, onion-peel colour, and flame colour. Those of orange are the same with those of crimson. Scarlet, besides the shades of all the rest, has some peculiar to itself, as cherry colour, fire colour, &c. See DYEING.

RED, in the *Manufacture of Glass*. See RED GLASS.

To make a deep red in glass, the following method is that most practised by the glass-men. Take crystal frit twenty pounds, broken pieces of white glass one pound, calcined tin two pounds; mix these well together, and put them into a pot to melt and purify. When these are melted, take steel calcined, scales of iron from the smith's anvil, both powdered very fine, of each an equal quantity; put leisurely an ounce of this mixed powder to the before mentioned metal; mix all well together, and let them stand six or eight hours in fusion to incorporate; take out a proof after this, and if there be too little of the powder, it will appear of a dusky yellow; then more of the powder must be added, and then add three quarters of an ounce of calcined brass, ground to a fine powder; mix them thoroughly together, and the mass will be of a blood red; continue stirring the whole together, and frequently taking out proofs of the colour, when it is right, work it immediately, otherwise it will lose its colour and become black. The mouth of the pot must in this process be left open, else the colour will be lost. Neri's Art. of Glass, p. 100.

RED, in *Heraldry*. See GULES.

RED, in *Painting*. For painting in oil colours they use a red called *cinnabar*, or vermilion; and another called *lacca*. See each in its place.

In limning and fresco, for a violet red, instead of lacca they use reddle, a natural earth found in England; for a brown red, they use burnt ochre, which is a native yellow earth, made red by calcination. It is chiefly brought from Oxfordshire; and burnt by those who prepare it in large ovens. The marks of its goodness are brightness of colour, and a friable chalky texture, without manifesting any gritty roughness when rubbed betwixt the fingers.

The common Indian red, which is of a hue verging to the scarlet, is much used, on account of its standing and warming though not bright colour, in finer as well as coarser paintings in oil. It may be prepared by taking of the caput mortuum or ochre left in the iron pots after the distillation of aqua fortis from nitre and vitriol, two parts; and of the caput mortuum or colcothar left in the long necks after the distillation of oil of vitriol, one part; breaking the lumps found among them, and putting them into tubs with a good quantity of water: and having left them to stand for a day or two, frequently stirring them, then lading off as much water as can be obtained clear from them, and adding a fresh quantity; repeating the same treatment till all the salts be washed out, and the water comes off nearly insipid. The red powder which remains must then be washed over, and, being freed from the water, laid out to dry. When this is designed for nicer purposes, it should again be washed over in basons.

The true Indian red is a native ochreous earth of a purple colour, brought from the island of Ormus, in the Persian gulf; and called, among the authors on these subjects, *terra Persica*. At present it is very rarely to be found; but it is certainly very valuable (there being no other uncompounded purple colour in use with oil) as well for the force of its effect, as for the certainty of its standing. In its genuine state, it needs no other preparation than grinding or washing over. It may be easily distinguished from any fictitious kind, by its being more bright than any other ochre which can be made so purple; and if it be rendered artificially purple by any addition, the fire will soon betray it; into which the genuine may be put without any hazard of change.

Venetian red is a native red ochre (see *VENETA bolus*), not much different from the common Indian red, but fouler; and may be easily prepared, by mixing common red ochre with the colcothar or caput mortuum taken out of the aqua fortis pots, and washed over. As it is generally used by the house painters in imitation of mahogany, it requires no other preparation than to be well ground with the oil with which it is used; but when it is used in miniature painting, it should be carefully washed over.

RED, *Blown*, in the *Porcelain Manufacture*, a name given to a peculiarly coloured china ware, of a spangled red, or to the colour alone that spangles it. It is an ornament easily introduced into use in our own manufactories of porcelain ware, and is done in the following manner. The colour is to be prepared of common copperas, calcined to a red colour in a charcoal fire, in a crucible, with another luted on the top of it inverted, and with a hole in its bottom. The signal of the calcination being finished, is, when the black clouds cease to come up through the hole, and a fine white thin vapour rises in their place. The vessels are to be then suffered to cool, and the red matter in them is to be reduced to a fine powder, while the vessels to be coloured with this

are yet wet. The operator is to provide a glass pipe, and covering one end of it with a piece of fine gauze, he is to dip this into the powder, and taking it carefully out, with that little is sticking to it, he is to blow against the vessel at some distance from it: thus the finest part of the powder only will reach the vessel, and will be laid on in form of

glittering spangles, very small, but all distinct. This is sort of colouring much esteemed by the Chinese themselves, and they have a way of using the common blue in the same manner; but few of the vessels thus painted come over to us.

Refining

REFINING, in *Metallurgy* and *Assaying*. In the former it signifies the means of obtaining metals from their ores, and from any other impurities, natural or artificial: for which see the metals under their respective heads. In the latter it is employed for ascertaining the quantity of the noble metals in the different alloys: for which see **CUPEL**; where the methods of refining in the furnace are fully treated. And for the humid process called *parting*, see **GOLD**.

It may be proper here to observe, that although the process of parting by nitric acid is still practised, we are inclined to recommend the method proposed by Bergmann, which consists in dissolving the alloy of gold and silver in nitro-muriatic acid. The silver falls to the bottom in the state of muriate of silver, and the gold is precipitated by the green sulphate of iron. The gold, by this means, is obtained perfectly pure, which is seldom the case in the process of parting. The trouble of testing to know what silver to add to the alloy, to make the gold equal to one-fourth of the silver, will be saved, and, with heat, the nitro-muriatic acid dissolves the gold quite as soon as the silver is dissolved in the common method. The muriate of silver, which is easily separated by washing, may be readily reduced by heating it with soda in an iron crucible. The soda combines with the muriatic acid, and is sublimed in white fumes.

REFINING of Sugar. This operation is begun by several strong lixiviums or leys of lime-water and eggs, shells, and all, mixed and beaten together.

The first refining is performed in the Caribbees, and other places, where the sugar-canes are cultivated; and only serves to make the brown or coarse sugars.

When these are imported into Europe, the sugar-bakers take them up, and refine them farther, by a second operation, or rather a repetition of the first.

To render the sugar very fine, fit for confections, &c. they give it a third refining; in which they only use the whites of eggs and their shells beaten together, and thrown into the melted sugar; which is called *clarifying the sugar*. See **SUGAR**.

REFINING of Salt-petre. The salt being put into an earthen or iron vessel, as much spring-water is poured on it as suffices to dissolve it. The vessel is then put over a gentle fire; and as soon as the water begins to boil, alum powder is thrown into it: the proportion is, one pound of alum to one hundred and twenty-eight pounds of salt-petre; and a little vinegar is added. As it boils, the scum is to be taken off; and it is to be evaporated till a pellicle appears on it, and then set to shoot.

For the refining of other matters, as camphor, cinnaabar, sulphur, salt, borax, &c. see **CAMPHOR**, **CINNABAR**, **SULPHUR**, **SALT**, &c.

Regulator

REGULATOR of a Watch, is a small spring belonging to the balance, serving to adjust the going, and to make it go either faster or slower.

REGULATOR of Velocity, in *Mechanics*, is a contrivance for regulating or governing the motion of a mill, or other large machine, by means of which it will always be caused to preserve an equable and regular velocity in the motion of its parts, notwithstanding any accidental increase of the moving force, or decrease of the resistance that may occasionally arise. A regulator must be connected with some lever, or other parts of the machine, which commands the supply of whatever constitutes its moving force, as the shuttle of a water-wheel, the sail-cloth of a wind-mill, or valve of a steam-engine; and it should have the property of acting suddenly upon this lever, or other part, the instant any increase or decrease of velocity in the motion takes place, either to elevate or depress it, and thus regulate the supply in a degree proportioned to the quantity of alteration in the velocity; and it is by the sensibility and accuracy of the regulator in this respect that its perfection is estimated.

The regulator most commonly used is called a *governor*. This consists of two or more pendulums suspended from joints, which are supported upon a vertical axis: this being caused to revolve by the machine, and the pendulums accompanying it, the balls will, by the centrifugal force, recede from the axis or centre a quantity proportioned to the velocity of the motion and length of the pendulum: then, on any accession of the motion, they recede still further from the axis, or *vice versa*, if the velocity diminishes. This motion is contrived to actuate the lever which regulates the velocity of the machine in a steam-engine: it is connected with the valve which admits the steam from the boiler to the cylinder, in a water-wheel with the shuttle, through which the water flows, or in a wind-mill with the mill-stones, or sail-cloths. See a farther description under **MILL-WORK**, **STEAM-Engine**, and **WINDMILL**.

The principle of the governor is the same with the circular or conical pendulum, of which Huygens has laid

claim to the invention, as well as of the long pendulum for regulating clocks, who says he discovered it nearly at the same time as the other. The conical pendulum circulates seconds when of the same length with the common pendulum, which will vibrate only half seconds. To explain it, we must suppose a ball or weight to be suspended by a string or rod, so that the ball can describe in a horizontal circle by a motion of the rod round a vertical axis, with which the centre of suspension coincides. In this motion the rod of the pendulum will describe the surface of a cone, of which the point of suspension is the vertex, and the horizontal circle which the ball describes is the base: it is hence called the circular or conical pendulum. The ball has liberty to recede from, or approach to, the axis, by moving upon its centre of suspension, and thus the circle the ball describes will be enlarged or diminished; and it is this circumstance which gives it the property of circulating or performing a revolution always in the same space of time which a simple pendulum of four times the length would vibrate; for this takes place equally whether the ball is extended to describe a large circle, or retracted to revolve in a small one; though, it should be observed, that this is only true in the supposition that the pendulum-ball, in moving from the vertical axis upon its centre, will describe a parabola instead of a circle, in the same manner as the ball of a common pendulum is required to move in the arc of a cycloid instead of a circle, to cause all the vibrations, both long and short, to be performed in equal spaces of time. Mr. Martin has, in his Institutions, given a very complete explanation of the principle of this pendulum, by supposing an inverted parabola, with its axis placed in a vertical position; then supposing a bowl or vessel excavated by the revolution of this figure upon its axis a paraboloid will be formed. A heavy globe or ball being put in this bowl, may, by agitating the vessel, be caused to perform a revolution in a horizontal circle within the vessel, and it will be found to circulate in the same period of time, whether it describes a small circle near the bottom of the vessel, or a large circle in its upper part, where the diameter is larger.

The governor or flying-ball is the regulator most generally used in machinery, although there are other means which, in particular instances, are preferable, from the circumstance of their possessing a greater power to operate upon the regulating part of the machine. One of these, called the water-regulator, consists of a pump, which, being worked by the machine, will raise water into a cistern, from which a constant stream flows off by a pipe and cock; a float is placed upon the surface of the water in the cistern, and this communicates with the steam-valve of the engine, or shuttle of the water-wheel. The operation of this regulator is easily explained, for the pump will raise a quantity of water exactly proportioned to the velocity of the machine, or the number of strokes it makes; whereas the stream which flows off by the cock is a constant quantity, and equal to that which the pump will supply when the machine moves with its intended velocity. When this is the case, the surface of water in the cistern will stand at the same height; but if the velocity is increased, the pump will raise more water into the cistern than the pipe and cock will carry off, and the surface rising, elevates the float, which, by its action to diminish the supply of power to the machine, will correct the acceleration which had taken place in its velocity. The opposite effect takes place if the velocity decreases, viz. that the supply to the cistern being diminished while the efflux is constant, the surface will sink, and the float descending, opens the valve or shuttle, and increases the supply of power to the machine until it regains the original velocity. The great advantage of this regulator is, that it can so readily be made to keep the machine steady at any velocity which may be required, and this by merely opening or closing the cock: thus, if it is opened to carry off a greater quantity, the surface will subside, and the float, by descending, opens a greater supply of power to the machine, and occasions it to move quicker; but this, though it raises more water by means of the pump, will not raise the surface of the water in the cistern to so great a height as it stood at before, because the efflux is now equal to the increased supply.

In all cases this regulator will cause the machine to work at such a rate, as to make the pump raise the same quantity of water as the cock emits, and its rate may be ascertained before it is put to work; for if the quantity of water which the cock will discharge in a minute, or other given space of time, is known, and the dimensions of the pump; then it may easily be calculated what number of strokes *per* minute the pump must make to raise an equal quantity of water. The sensibility of this regulator will be increased by making the cistern of a small size, because then any deviation from the intended rate of working will cause the greater elevation or depression of the surface, and a greater action on the float: and, for the same purpose, it is best to make the cistern gradually diminish in area, so as to be smaller both towards the top and at the bottom, than at the place where the surface is expected to stand when the machine moves with the proper velocity. By this means it will rise or fall more rapidly, in consequence of the diminished area of the cistern, when the alteration of velocity is considerable, and a greater correction is required, than when the alteration is only trifling. It is necessary that the pump should raise a constant stream of water into the cistern, both in the ascent and descent of its bucket: to do this, two pumps, acting alternately, may be used, or by a very simple contrivance a single pump may be made to effect the same; thus, upon the rod of the pump a cylinder of wood is fixed, which is of such a diameter, that its area is equal to half the area of the pump-barrel, and its

length being equal to the length thereof, its content will be equal to one-half of the barrel: this is fixed on such a part of the rod, that it will, by the rising and falling of the rod, be drawn up out of water as much as the rod and bucket moves: now, when the pump-bucket is drawn up, the rising of the cylinder above the surface of the water increases the capacity of the cistern one-half as much as the quantity of water which is thus drawn up into it, and the efflux of water by the cock being just equal to the other half, the surface will be stationary; and when the bucket descends, and no water is raised, the cylinder going down into the water diminishes the capacity of the cistern a quantity equal to the quantity of water which will flow off in the same time, and thus supplies the waste of water which flows off in the same time. A regulator of this kind may, in many cases, be formed from some part of the machine, without any additional apparatus: thus, the cold water-pump of a steam-engine will raise the necessary water into a cistern for the float to act in, and this float must be connected with the arm of the steam-valve. Also, in an engine for blowing a furnace, where it has a water-regulator (see BLOWING), the rise of the water in the external cistern may regulate the motion of the engine, the whole machine being of the same kind with the regulator we have described.

A regulator would be applied with great advantage to a machine which is used in the *Cotton MANUFACTURE* (see that article), for drawing a piece of cotton cloth regularly and slowly over a red-hot cylinder of iron by two rollers, from one of which it is wound to the other: now, if the men who turn these stop but for a moment the cloth is burnt through, but by a regulator it might be lifted off the hot iron the instant the motion was so far diminished as to endanger the firing of it.

The water-regulator is rendered more powerful by suspending the cistern from the end of a lever, like a scale-beam, the opposite end of which has a counterpoise sufficient to balance the weight of the cistern when the water in it stands at the intended height; but if the water increases in the cistern from the causes above described, the box will descend, and the motion of the lever will act upon the machine to make the regulation the same as the motion of the float: on the other hand, when the water in the cistern diminishes, the counterpoise will draw it up and give motion to the lever. The water from the pump is introduced to the cistern by a spout, and all the other parts have the same construction as we have described.

It is a defect of both the regulators we have above described, that they do not operate upon the machine until the alteration of velocity has actually taken place, although they immediately correct it. It would be desirable to have others which would make the correction before the evil takes place: for instance, in a wind-mill, which is more subject to irregularity than any other machine, a large vane may be suspended by a heavy pendulum, and opposed to the wind; now the force of the latter, when blowing regularly, will cause the pendulum to incline a certain quantity from the perpendicular; but if the wind increases or diminishes, it will incline more or less, and this motion may be communicated to the shuttle which regulates the feed of corn, so as to give more or less to the stones in proportion to the power of the wind for grinding it, thus adapting the resistance to the power; and if this should increase beyond all bounds, the same motion may be made to act upon the grip of the mill to check its acceleration effectually. In the same manner a water-wheel may have a float placed in the dam or head to act upon the shuttle whenever the surface thereof rises or falls above or

below the intended level, so as to apportion the supply to the fall, and keep the velocity uniform.

There is another kind of regulator sometimes used in machines to cause a sufficient resistance to the motion to prevent acceleration, such as a crane or lowering machine, which is to let down a heavy weight, a coal winding machine, &c. ; a very good one for these purposes is a vertical axis with

pendulums, like the governor, but having a broad vane to meet the air instead of heavy balls, which indeed may be added also : this, when put in motion, will oppose a very great resistance to the acceleration, because the centrifugal force causing the vanes to recede from the centre, they must describe a larger circle in the air in proportion to the velocity, or, by collapsing, they make but little resistance when the velocity is small.

Rentering

RENTERING, FINE-DRAWING, in the *Manufactories*, the sewing of two pieces of cloth, edge to edge, without doubling them ; so as that the seam scarcely appears at all : hence it is called *fine-drawing*.

The word is formed from the French, *rentraire*, which signifies the same thing ; and which Menage, after Salmasius, derives from the Latin, *retrahere*, of *re*, *in*, and *trahere*, by reason the seam is drawn out of sight, and covered.

Serges, &c. are to be sewed : cloths fine-drawn. The author of one of the *Let. Edif. et Cur.*, speaking of the great dexterity of the fine-drawers in the East Indies, assures us, that if you tear a piece of fine muslin, and give it one of them to mend, it shall be impossible for you to discover the place where it is rejoined, even though you had made a mark to know it by.

The dexterity of our own fine-drawers, though inferior to that above-mentioned, is nevertheless such, as puts them in a condition to defraud the king, by sewing a head or slip of English cloth on a piece of Dutch, Spanish, or other foreign cloth ; or a slip of foreign cloth on a piece of English, so as to pass the whole, as of a piece ; and by that means avoid the duties, penalties, &c. The trick was first discovered in France by M. Savary, author of the *Diction. de Commerce*.

To *renter*, in *Tapestry*, is to work new warp into a piece of tapestry damaged, eaten by the rats, &c. and on this

warp to restore the ancient pattern, or design. The warp is to be of woollen, not linen. Among the titles of the French tapestry-makers, is included that of renterers.

Fine-drawing is particularly used for a rent, or hole, happening in the dressing or preparing of a piece of cloth, artfully sewed up or mended with silk.

All fine-drawings are reputed defects or blemishes ; and ought to be allowed for in the price of the piece. Hence, M. Savary establishes it as a rule, which is certainly founded on natural equity, that every manufacturer mark the fine-drawings of his cloth with a piece of packthread tied to the list ; to direct the draper to the spot : and that the draper apprise the taylor, or other person to whom he sells it, of the same, that he may not come to damage in the cutting ; there being instances of drapers condemned to take back their cloth, when cut to pieces, for omitting to mention the fine-drawings, and other flaws.

On this occasion. M. Savary extols the procedure of an English merchant, who, lending a piece of cloth damaged in one spot, to his correspondent at Paris, put a piece of gold in the damaged place, to make up the damage. But as this example is perhaps the only one of its kind, that author recommends it to the merchant, or draper, to unfold all the pieces entirely, as they come to him ; to discover the fine-drawings, and other flaws, in order to make the clothier accountable for them.

Road

ROAD, VIA, an open way or passage, forming a commodious communication between one place and another.

The Romans, of all people, took the most pains in their roads; the labour and expence they were at to render them spacious, straight, smooth, and agreeable, to the very extremities of their empire, are incredible.

Usually, they strengthened the ground by ramming it, laying it with flints, pebbles, or sand; sometimes by a lining of masonry, rubbish, bricks, potshreds, &c. bound together with mortar.

F. Menestrier observes, that in some places in the Lyonnais he has found huge clusters of flints cemented with lime, reaching ten or twelve feet deep, and making a mass as hard and compact as marble itself; and which, after resisting the injuries of time for sixteen hundred years, is still scarcely penetrable by all the force of hammers, mattocks, &c. and yet the flints it consists of are not bigger than eggs.

Sometimes they even paved their roads, regularly, with large square free-stones: such are the Appian and Flaminian ways, &c.

The roads paved of very hard stones, they usually called *via ferrea*, either because they resembled iron, or because they resisted the iron of the horses feet, chariots, &c.

Roads are either *natural* or *artificial*, *terrestrial* or *aquatic*, *public* or *private*.

ROAD, Natural, is that which has been frequented for a long succession of time, and subsists with little expence by reason of its disposition, &c.

ROAD, Artificial, is that made by labour of the hand, either of earth or masonry; and in the making of which, several difficulties were to be surmounted; such are most of those along the banks of rivers, and through marshes, lakes, &c.

ROADS, Terrestrial or Land, are not only those made upon the ground, but also those formed of earth heaped up in manner of a bank, and sustained by spurs, buttresses, and counterforts.

ROAD, Aquatic, is a road made in the waters, whether current, as those of rivers, &c. or stagnant, as banks and causeways, or over morasses, &c.

Under this denomination are also comprehended navigable rivers, and artificial canals. See CANAL.

ROAD, Public, or *grand road*, is any common road, whether straight or across, military or royal, &c. **Private** road is that made for the convenience of some particular house, &c. See HIGHWAY.

ROADS, Military, so called among the Romans, were

grand roads appointed for the marching of their armies into the provinces of the empire, for the assistance of their allies, &c.

The principal of these roads, in England, are Watling-street, Ikenild-street, Foss-way, and Erminage-street. See WAY.

ROADS, Double, among the Romans, were roads for carriages, having two pavements or causeways, the one for those going one way; the other for those returning the other, to prevent clashing, stopping, and confusion.

These two ways were separated from each other by a bank raised in the middle, paved with bricks, for the convenience of foot people, with borders and mounting stones from space to space, and military columns to mark the distance. Such was the road from Rome to Ostia, called *Via Portuensis*.

ROAD, Subterraneous, is that dug in a rock with a chisel, and left vaulted. Such is that of Puzzuoli, near Naples, which is near half a league long; and is fifteen feet broad, and as many high.

Strabo says, it was made by one Cocceius, a relation probably of Nerva; but it has since been widened by Alphonfus, king of Arragon and Naples, and made straight by the viceroys. There is another of the same kind in the same kingdom, between Baix and Cumæ, called the Grotto of Virgil, because mentioned by that poet in the sixth book of his *Æneid*.

ROAD, in Rural Economy, a track or way constructed with some sort of hard materials for the purpose of travelling upon, with carriages, horses, and other animals. Roads are of different kinds, as public and private, or parochial. The first sort may be subdivided into toll and free-roads, and the latter into lanes or bye-roads: there are likewise other sorts of roads, as carriage and horse tracks, &c. It has been remarked by a writer, in the first volume of "Communications to the Board of Agriculture," that the conveniences and beneficial consequences which result from a free and easy communication between different parts of a county and district are so various, and the advantages of them so generally and extensively felt by every description of individuals, from the highest to the lowest; that no labour or expence should be spared in providing them; as, without such ready means of intercourse, all sorts of internal commerce and improvement are either much embarrassed, or wholly at a stand. And it is, indeed, well added, that roads and canals, or navigable rivers, may justly be considered as the veins and arteries through which all improvements flow. To internal commerce and agri-

culture, they are as the veins and arteries to the human body. Through these the blood circulates in every direction, and thus keeps alive the animal system; but, if this circulation is by any means checked or obstructed, even in the remotest part, that part soon becomes useless, and sinks into decay, and in some degree is felt throughout the whole body. So it is with respect to the commercial and agricultural systems. Without a free and uninterrupted intercourse, it is impossible they can exist, or at least produce, to the community at large, so many important benefits as they otherwise might have done. How many, for example, are the places, in almost every country, that might be rendered doubly valuable, if the access were practicable and easy. How immense the quantities of the finest timber, perhaps growing in inaccessible woods, which, on that account alone, are lost to society. How many the valuable strata of the richest metals and minerals, which, from the same cause, lie buried and undisturbed in the bowels of the earth; and how many thousands of acres of the most fertile soil, that might be improved and cultivated to the highest degree of perfection, and thus very largely contribute to increase the food and the comforts of man, were the ingress and egress rendered practicable and free. And the value of a farm, consequently the riches, perhaps the strength of a country, greatly depend on an easy and uninterrupted communication by good roads.

And the able author of the "Wealth of Nations" has well suggested, that good roads, canals, and navigable rivers, by diminishing the expence of carriage, put the remote parts of the country more nearly upon a level with those in the neighbourhood of the town. They are, upon that account, the greatest of all improvements. They encourage the cultivation of the remote, which must always be the most extensive circle of the country. Though they introduce some rival commodities into the old markets, they open many new markets to its produce. It is even further observed, that the Romans were so sensible of this, that we are told, the first writer says, they did not think it beneath the dignity of the commonwealth to attend to the conveniences from good roads. That great and wise people, it is said, carried on, at an immense expence, roads, whose remains are to this day the admiration of the curious, from the centre of the empire to many of the remotest provinces. The reader march of their armies was, perhaps, he thinks, their first motive; but the easier intercourse of the several parts of the great empire was another, which they had too much prudence and too much wisdom to overlook. We are also told by Diodorus, Strabo, and other historians, he says, that the famous Semiramis, being so fully convinced of the importance of an easy and general intercourse, applied herself to render the roads practicable throughout the whole extent of her empire.

Mr. Donaldson also states, that, in an agricultural view, the benefits derived from good roads are incalculable. Before the establishment of turnpike roads in England, many parts of that kingdom, like the highlands of Scotland, were scarcely accessible. Coal, manure, grain, &c. as is still the case in many parts of Cornwall, were carried on horses' backs. Where waggons were used, seven or eight horses were necessary to draw about two tons, and seldom were able to proceed above twenty miles in a day. Now, where turnpikes are established, or other means used for keeping the roads in a proper state of repair, the same number of horses will draw at least five tons, and travel nearly double the distance, with much more ease. How absurd, then, continues he, for any person to scruple the payment of an in-

considerable toll, when the saving is so great and so evident; where the tear and wear in one case are not one-twentieth part of what they are in the other!

It is likewise contended by Mr. Beatson, in respect to the turnpike laws in this country, that they are liable to many exceptions; for although immense sums of money are annually levied for the purpose of making and repairing the highways, yet, either from bad management, from party influence, or from the chicanery and ignorance of surveyors and contractors, the roads in many places are not only laid out in the most absurd direction, but are so badly constructed, and kept in so wretched a state of repair, that they are almost impassable. It is surprising that in so enlightened a country, and where the turnpike laws have so much engaged the attention of many very ingenious men, those laws should still remain so very defective; more especially as there is hardly a country gentleman who attends a turnpike meeting, but considers himself completely master of the whole business and management, as well as of the making of roads; at least, if we may judge from the violent disputations and bickerings that frequently happen at these meetings, where a proposed new line of road, or perhaps the repair of an old one, will sometimes be contested with as great keenness and vehemence, as if the parties were contending whether Great Britain shall be a monarchy or a republic. And it is contended, that it too often happens party influence rules the proceedings at such meetings, and that those who are entrusted with the management of this business, delegate their powers, and trust the inspection and whole management and direction of the roads to some ignorant or pretended surveyor; who, almost to a certainty, will impose upon them, especially if he is empowered to settle with contractors; and thus the business of the public, one of its most important concerns, is either altogether neglected, or terminated according to the convenience of the strongest party, without any regard to the interests of the community at large. In support of this assertion, he has only to refer to many parts of the principal thoroughfares in Britain. In some, it will be observed, the roads are directed in the most irregular zigzag manner, through a level part of the country, where they ought evidently to have gone straight forward. In other places, the traveller and the public, and the poor overloaded horse, are obliged to submit to all the inconvenience, the labour, and the fatigue of ascending and descending the steepest hills, when they might have gone, with the greatest ease and comfort, on a level road, by proper attention in the first making and laying them out. He is, however, far from thinking it would either be just or proper to force a road unnecessarily through any part of a gentleman's property without his consent, unless for very powerful reasons indeed.

If to avoid a deep ascent, or to shorten the distance considerably, and that there is no other way to do so, in that case there should be no hesitation; but if the advantages to the public are not very material, and that another line can be adopted, nearly as good, which will do less injury to an individual, the latter line should unquestionably be preferred in all such cases of laying out roads.

It should be a general maxim, he thinks, that private considerations ought, in all cases, to give way to public convenience and advantage. Society, says he, is formed for the mutual and general benefit of the whole, and it would be a very unjust measure to incommode the whole, merely for the convenience, or perhaps to gratify the whim or caprice of an individual. However, the property of an individual ought by no means to be taken to serve the

public, without allowing him, not only the full value, but more than the value proportioned to the inconvenience or injury he may sustain by the measure.

But he contends, farther, that while the present turnpike laws remain in force, and the common mode is practised of choosing surveyors annually, or by rotation, without the smallest regard to abilities or experience, it cannot be expected the public convenience will be so much attended to as it ought to be; neither is it to be expected, that the generality of surveyors, so chosen, can know the proper directions to give in making or repairing roads, nor the proper manner of making estimates, so as either to conclude an agreement with an artful contractor, or to form a correct judgment of such proposals as may be made. From these disadvantages, it is inconceivable the loss that may be occasioned, or the mischief that may be done by an ignorant and inexperienced surveyor. For he is decidedly of opinion that a surveyor of roads should be a man of considerable abilities, and of the strictest honour and integrity. A man not apt to be swayed by party influence, or by private or personal considerations; for if he once allows himself to be led away or biased by those, or to act in any manner inconsistent with the public interests, he is unfit for that office. He ought not to be a man, who has all his life-time been confined to the narrow limits of a single district or county, or who has suddenly, or by a slender recommendation, been brought forward as a person qualified for so arduous an undertaking. He ought to have seen, in various places, the different systems adopted in the management and construction of roads, and to have made it a particular object of his attention, the judging of the best and most advantageous practices, under the particular circumstances of different cases. And besides these, there is another probable reason why, under the present system, the public roads cannot be so impartially managed and conducted as they ought to be, in the unlimited power given to country gentlemen over the roads in the county or district in which they live. Many of those gentlemen, for their benevolence and liberality, are truly deserving of every praise that can be bestowed upon them; but, however honourable and respectable they may be, and however desirous to promote the public good, it would be doing an injustice to human nature to suppose they can view, with impartial eyes, the fine plantations, the beautiful inclosures, and other improvements, they have made on their estates. We may as well imagine, that a doting mother can coolly and deliberately see an incision made in the skin of her darling child, however much it may be benefited by the operation, as that a country gentleman can with indifference behold a turnpike road carried through an inclosure, which he himself has been at the pains and the expence of adorning. He adds, that so situated, it is natural to believe this gentleman would wish that road to go in any other direction, even though it should not be quite so convenient to the public. He will not only use his own persuasion and endeavours to point out arguments against its coming that way, but he will even endeavour to prevail on his friends to exert themselves also, and thus a party is often formed in opposition to the public interest; and if he is a man of opulence and power, and generally respected, it is more than probable his influence will prevail in this business.

It consequently appears to him necessary, in order to obviate these abuses and inconveniences, that there should be a controlling power over the measures proposed by country gentlemen respecting turnpike roads: for to allow those gentlemen to decide ultimately on the laying out a

new road through their own lands, or even on the distribution of the money to be expended in repairing old roads, is, in fact, making them judges in their own cause. In short, it is an object so truly important to the interests of the community at large, and of the kingdom in general, to procure the most easy, safe, and expeditious, and the least expensive intercourse with every part, by means of the best roads, that it is a measure, he presumes, highly deserving the attention of the legislature; and which, from the great extent of business, would probably require a board, with proper surveyors appointed by it, for the purpose. If some plan of this nature were adopted, we should then hear no more of those numerous complaints that are so often made respecting the abuses committed in the management of turnpike roads, and of the money levied at the toll-bars, at many of which, it is said, by the author of the "Wealth of Nations," the money levied is more than double of what is necessary for executing, in the completest manner, the work which is often executed in a very slovenly manner, and sometimes not executed at all.

But in respect to the improvement of both the public and private roads, the following hints have been thrown out in the able Agricultural Survey of Shropshire. In lieu of surveyors in each parish (who are generally chosen in turn, and consequently have neither time nor experience sufficient to act properly, and are generally not inclined to exert themselves by enforcing the duty, &c.), the writer would propose for the magistrates to have power to appoint a proper surveyor with a salary, who should act under their direction, and be amenable to them for his conduct; such surveyor to undertake the arrangement of a certain district (say ten miles square), whose duty it should be to employ deputies, to call in and see the statute duty done under his direction: by this means the forming of the roads, which is the first principle, would be done in the most approved method, and the statute duty regularly called out. There may be an inspector, an inhabitant in each parish, appointed, and chosen yearly, whose interest it would be, as well as his duty, to act as a check upon the general surveyor and his deputy: this office, being easy, might be filled by one of the most liberal persons in the parish. He apprehends that an arrangement of this sort would very soon insure good private roads. And something like the following would, he thinks, procure good turnpike roads also; namely, the trustees of all the turnpike roads throughout England, to be obliged to erect weighing engines at all their gates or bars, at which tolls are received, on or before the 24th day of June next, the expence of such erections to be repaid to them, by their being empowered to add to their present respective tolls any sum to be paid by such carriage to be weighed, not exceeding so much as has been heretofore paid within one year last for the tolls; such sums to be paid, until all expence of erecting the said engines shall be fully repaid. The account of such repayment to be made out and settled by the clerks and gate-keepers belonging to the respective roads, and to be attested upon oath before two justices of the peace. And from and after the said 24th day of June next, it may be lawful for all carriages to be drawn with any number of horses along any turnpike road. But to prevent the injuries done to roads, by the great burdens too frequently drawn along them, it should be enacted, that from and after the said 24th day of June, it should be lawful for all trustees appointed by any act or acts of parliament, for the repair of any turnpike road, or any five or more of them, and they should be required at a public meeting, to be held

for that purpose on or before the 24th day of April next, to order to be erected at all the gates and bars which they have erected, or shall erect, for the receiving of tolls, or upon any part of the road within their respective jurisdictions, and at such a distance from any turnpike, bar, or toll-gate, as they shall think requisite and expedient to order and cause to be erected, a crane, machine, or engine, proper for the weighing of carts, waggons, or carriages conveying any goods or merchandize whatever; and by a writing signed by them, or any five or more of them, to order all and every such carriage or carriages which shall pass loaded through any such gate or bar, to be weighed, together with the loading thereof; and for them, or any five or more of them, or for any person or persons empowered by any five or more of them, to receive and take, over and above the tolls already granted, or hereafter to be granted, the sum of 10s. for every hundred weight, 112lbs. to the hundred, which every waggon or cart hereafter described, together with the loading thereof, shall weigh over and above the weights hereafter allowed to them respectively; that is to say, to every waggon or four-wheel carriage, having the fellys or rollers of the wheels of the breadth of sixteen inches, eight tons in summer, and seven in winter: to every waggon or wain, having the axle-trees thereof of such different lengths, that the distance from wheel to wheel of the nearer pair of the said wheels be not more than four feet two inches, to be measured at the ground, and that the distance from wheel to wheel of the other pair thereof be such, that the fore and hind wheels of such waggons and wains shall roll only one single surface or path of sixteen inches wide at the least, on each side of the said waggons or wains, and having the fellys thereof of the breadth of nine inches from side to side at the bottom or sole thereof, six tons ten cwt. in summer, and six tons in winter: to every waggon or four-wheel carriage, having the sole or bottom of the fellys of the wheels of the breadth of nine inches, six tons in summer, and five tons ten cwt. in winter: to every cart, having the fellys of the same dimensions, three tons in summer, and two tons fifteen cwt. in winter: to every waggon, having the sole or bottom of the fellys of the wheels of the breadth of six inches, four tons five cwt. in summer, and three tons fifteen cwt. in winter: and to every such waggon, so constructed as to roll, and actually rolling a surface of eleven inches by the wheels thereof, five tons ten cwt. in summer, and five tons in winter: to every cart having the fellys of the same dimensions, two tons twelve cwt. in summer, and two tons seven cwt. in winter: to every waggon, having the sole or bottom of the fellys of the wheels of less breadth than six inches, three tons fifteen cwt. in summer, and three tons twelve cwt. in winter: and to every cart, having the fellys of the same dimensions, one ton fifteen cwt. in summer, and one ton to twelve cwt. in winter. And if such trustees as aforesaid shall neglect to erect such engine at their respective gates by the said 24th day of June, then it shall and may be lawful for any mortgagee or mortgagees of the said gate or gates to erect such engine or engines, and to take upon them the same power as the said trustees were by the act invested with, and under the same regulations, on or before the 29th day of September next; and if the said trustees and mortgagees shall neglect to erect such engine or engines by the respective times hereinbefore stipulated for erecting the same, then it shall and may be lawful for all horses, carts, and other carriages, from and after the said 29th day of September next, to go through and pass along such road or roads, without any obstruction or payment for tolls whatsoever, until such

trustees or mortgagees shall erect such weighing engine or engines as aforesaid, and occasion the same to be regularly used; any thing contained within the respective acts for turnpike roads to the contrary notwithstanding.

And it is usefully remarked, in respect to the effects of these regulations, that, first, the weighing engines will sufficiently prevent carriages of all sorts being overloaded, which will be a preservation of the road, whereas, the restraint upon the number of horses does not answer the purpose; for a short and overpowered team does more damage to the roads, than a greater number of horses, which draw easy, and consequently pass along much quicker. That disagreeable restraint will be thereby made unnecessary, which empowers and encourages some poor indolent wretches to wander about the country with their ready printed notices, to catch a prey, which, when got, is lavished away in drunkenness, debauchery, and disorder; and if they fail in their lawful attempt, which is often the case, and perhaps distressed to the greatest degree, being despised by persons of all denominations, pursue poaching and fowl-stealing, which lead to greater acts of thievery, of which there are many instances; for all the convictions are grounded upon the poor wretches as above described, being by the law allowed to be credible witnesses, who obtain the reward to the amount of 5*l.* or more, when the team-owner's servant or servants are all deemed prejudiced; so that, as the act now stands, no one is safe from these convictions.

Besides, the occupiers of farms in general, particularly those upon the middling-sized ones, find themselves, it is said, very much oppressed and injured by the law now subsisting for regulating the turnpike roads, by their being restrained from drawing more than four horses in waggons, the fellys of the wheels thereof being under six inches broad. Were farmers permitted to draw any number of horses, it would be of great public utility in lowering the price of those animals, which is now enormously high; the farmer would find it his interest, as formerly, to keep breeding mares, which, with the colts they breed, may be made useful great part of the year, provided they may be worked easy. The law, as it now stands, acts nearly as a prohibition to farmers breeding horses; for a breeding mare, or a colt under five years old, is not fit to draw one of four in a waggon, with no more than sixty bushels of barley or wheat, which is the common load of the Shropshire or Staffordshire farmers, neither of which bring more than two tons, which is considerably under the weight the present act allows to be drawn on the turnpike roads in winter. Before the said turnpike laws were in force, the farmer's team, to draw his sixty bushels of wheat or barley, consisted of six in number, two of which at least were mares, either in foal or sucklers, two colts, one of them two, the other three years old, which were never oppressed or hurt by their work; consequently a succession came on, and the owner had one or two good sound colts to sell off every year to the harness or draft, as they best suited. Good waggon horses were then bought at from 10*l.* to 15*l.* each, which are now, by their scarcity, from 25*l.* to 35*l.*; and those for the coach, that is, the light active half-blood horses, are from 40*l.* to 60*l.*

And another evil occasioned by this law is, that such farmers are obliged to keep horses of the largest size, which consume the produce of much land, by eating a large quantity of corn, when the smaller horses, working easy, seldom eat any. It is conceived by the same writer, that upon this principle, a law for regulating roads may be enacted, so as to answer every good design of the present, and at the

same time relieve those individuals who are exceedingly injured, and also be of general utility.

It is likewise remarked in regard to private roads, that they are by no means properly attended to; and which may be attributed to the general highway act being so easy of evasion, that every farmer is able to avoid doing statute duty, or at least next to none. Nothing is more valuable than time, especially to a man of business; and a farmer who executes the office of surveyor of the highway, *impartially and effectually*, will find he must neglect no small part of his own business; and after all he might, perhaps, have been as little out of pocket had he done the whole work with his own team and labourers. It is stated, that there is no trick, evasion, or idleness, that shall be deemed too mean to avoid working on the road; sometimes the worst horses are sent, at others a broken cart, and a boy, or an old man past labour, to fill; they are sometimes sent an hour or two too late in the morning, or they leave off much sooner than the proper time, unless the surveyor watch the whole day. It is true, that redress may be had by application to a magistrate; but then how often causes of complaint occur; and how many days must be lost to bring each home to the offender; who, *from custom*, thinks he is doing no harm; besides the constant breach of good neighbourhood that must be occasioned by these petty litigations. It is suggested that a remedy might easily be had in the following manner. Abolish all personal service upon the highways. Let surveyors be appointed, as at present, who should have power, under the authority of two magistrates, to raise, by rate, certain sums that may be necessary for the repair of the roads within the respective parishes and townships, and to account for the same at going out of office at the year's end. The farmer, who acts as surveyor, might then be able to repair the highways when most convenient to himself, and when he could give attention to them without any interruption or impediment, whereas at present some duty is given up, or nearly so, from the difficulties arising in collecting it. On the same principles, the author of the *Present State of Husbandry in Great Britain* contends, that an act of parliament should be introduced, for the purpose of rescinding the ancient laws respecting statute labour; which have in every instance been found ineffectual, and to establish other general rules and regulations more likely to answer the purpose in the new improved state of the country. He adds, that the existing acts of parliament respecting the making and repairing roads, where the justices of the peace cannot commute the statute labour, are not sufficient for the purpose of raising a fund sufficient for keeping the roads in repair. Where the justices of peace have it in their power to assess the inhabitants in a sum of money in lieu of the statute labour, it is in general not the want of means, but the misapplication of that means, or negligence in the general management, that is the cause why the parish roads are almost every where a disgrace to the country. The imperfect and indifferent modes of executing the statute work, as stated above, render it necessary, it is supposed, that those statutes enforcing the performance of this necessary duty should therefore be abolished; and in every county the justices of the peace ought to be invested with the power to assess the inhabitants of the district by some equitable *ratio*, whereby they would pay only in proportion to the benefit they received. Were this generally done, as is the case in several parts of Scotland, the counties divided into districts of such size, that the proprietors could conveniently meet as occasion required; the money arising from the commutation act collected by one person, who should be allowed a certain *per*

centage on the sum collected, be continued during good behaviour, and be responsible for his conduct to the gentlemen of the district; the money so collected be afterwards expended under the direction of these gentlemen, and the whole be subject to the review of the quarter-sessions; the parish roads would, it is supposed, soon be materially improved. If to these regulations a power were added to mortgage the sum arising from the commutation of the statute labour for such a number of years, and to such an extent, as was found necessary to put the useful private roads in a perfect state of repair, they might, it is supposed, in a few years, be made the reverse of what they are at present. The last measure would be found the most effectual of any that could be adopted, and is probably the only one that can be resorted to for the purpose of effecting an immediate and general improvement.

It has likewise been remarked by the author of the "*Landed Property of England*," in respect to the improvement of farm-lands by these means, that the art of planning, forming, and repairing roads, is a subject with which, for various reasons, every manager of a large estate ought to be familiarly conversant. It is not enough for him to know the theory, or general principles, of the art. It is necessary that he should study it practically in the particular district in which he is placed; and with the given materials that it happens to afford; as by these means he can only be capable of executing the business with the greatest possible advantage. In this business a most material point, whether in the *laying out of new roads*, or *improving* such as have been long established, is that of giving them all the advantage in direction and other circumstances that the peculiarity of their nature and situation admit of. It has been stated by the above writer, that most of all the old roads of the kingdom (the remains of the Roman ways excepted) owe their present lines to fortuitous circumstances. Many of them were, no doubt, he thinks, originally foot-paths; some of them, perhaps, the tracks of the aboriginal inhabitants, the patriarchal savages, who lived by hunting; or of the pastoral tribes, who travelled with their flocks and herds from pasture to pasture, as herbage and browse invited; or of the first settlers, between bidding places which may not now exist. And that these incidental foot-tracks, especially when they led through woods, became, as the condition of society advanced, the most convenient horse-paths; as we not unfrequently find at the present day. Consequently, that in this state of society, before wheel-carriages were in use, many of the lands of the kingdom were appropriated, by which circumstance those fortuitous lines of roads became fixed and unalterable; there being no other legal lines left for carriage roads, than those incidental horse-ways, or small tracks. He supposes, that in this account of the probable origin of roads, we have, at least in part, the cause of the crookedness, as well as the steepness, of carriage roads, between the places which are now inhabited: for true it is, that the traveller is not unfrequently led down one steep to make an angle, and ascend another; while the hang of the hill would conduct him nearly on a level, and by a more direct line. But, admitting that a cluster of habitations heretofore stood at the angle, the seeming absurdity ceases. He adds, that formerly, it is probable, the zigzag direction of roads, between towns and villages, was much more observable than at present. In more modern times, and since the legislature wisely interfered with respect to appropriated lands, many improvements of lines have been made. And, by the general laws which have more recently been passed, magistrates are invested with authority to alter established lines. So

that now, the expence of alteration may be said to be the only obstacle, in ordinary cases, to the perfection of the lines of roads in this country. And which is, of course, a circumstance that has had much effect in improving the convenience of travelling.

And it is suggested, in respect to the direction of roads, that the most perfect line is that which is straight and level. But this is to be drawn in a country only which is perfectly flat, and where no obstructions lie in the way:—joint circumstances that rarely happen. Where the face of the country, between two points or places to be connected by a road, is nearly but not quite level, by reason of gentle swells that rise between them, a straight line may be perfect;—may be the most eligible under these circumstances. But where the intervening country is broken into hill and dale, or if one ridge of hill only intervenes, a straight line of carriage road is seldom compatible with perfection. And that in this case, which is nearly general, the best skill of the surveyor lies in tracing the midway between the straight and the level line. Here the level line of perfection, for agricultural purposes, is to be calculated, by the *time* and *exertion* jointly considered, which are required to convey a given burden with a given power of draft from station to station. On great public roads, where *expedition* is a principal object, time alone may be taken as a good criterion. It is likewise added, that the most regular method of finding out the true line of road, between two stations, where a blank is given,—where there is no other obstruction than what the surface of the ground to be got over presents,—is to ascertain and mark, at proper distances, the *straight line*; which is the only certain guide to the surveyor. And that where the straight line is found to be ineligible, each mark becomes a rallying point, in searching on either side of it for a better. If two lines of equal facility, and nearly of equal distance from the straight lines, present themselves, accurate measurements are to determine the choice. If one of the two best lines, which the intervening country affords, is found to be easier, the other shorter, the ascent and the distance are to be jointly considered, the exertion and the time required are likewise to be duly weighed. Further, also, the nature of the ground, the source of materials and, generally, the comparative *expence* of forming the road by two doubtful lines, as well as their comparative *exposure*, are to be taken into consideration. A long line of road, across a broken country, should not be hastily drawn or determined upon by the directors of this sort of business.

But in regard to the most difficult and troublesome part of this sort of work,—the necessary management in the ascent of hills,—it is observed that, whether in laying out a fresh line, or in altering an established one, modern road surveyors, like many other reformers, have run from one extreme to another. To do away the absurdity of going up one steep and down another, to ascend a third in order to reach the required elevation (a common occurrence on fortuitous roads), they have ingeniously, but very injudiciously, given an uniform rise from the bottom to the top of the ascent. In the theory of mechanics, and where mechanic powers only were to be used, a regularly inclining plane would be perfectly proper, in a case of this kind. Where the requisite power is to be applied by rational beings, the same principle, though not altogether perfect, may be allowed; but when the moving power is neither purely mechanical, nor in a sufficient degree rational, but an irregular compound of these two qualities, the nature and habits of this power require, he thinks, to be consulted. It is, he conceives, one of many instances, which shew the impropriety of applying purely mechanical principles, in agricul-

ture and rural concerns, in which they are to be combined, not only with the power but the will of the animals. No man who has been accustomed to drive a road team, or in the habit of seeing one driven in a hilly country, and who properly regards what he sees, would lay out a long line of ascent without one or more breaks, or convenient resting-places; in which the animals of draft may relax at their ease, and set off again without difficulty. He, however, observes, theory will readily suggest that, by a drag-staff, or pail, a carriage may be securely stopped on the steepest ascent. But practice well knows the danger of checking the efforts of beasts of draft while they are struggling against the collar. For if they possess any habits, or even the seeds of restiveness, nothing is, he contends, more likely to encourage, or produce it, than suffering them to stop under the difficulties of draft. Besides, those which are true to their work, well knowing the extraordinary difficulty to be overcome, in putting a carriage at rest into motion in such a situation, stop under a degree of anxiety; while the more spirited and irritable stand on the rack, and tremble at the apprehension of the painful effort they have to make. But let them see an end, or a respite, of their endeavours, and they will struggle with willingness. A rest, after the difficulty is surmounted, comes as a reward for their exertions. But where the natural surface of the ground is well studied in any given case, there will seldom, he supposes, be much difficulty in assigning the places proper for rests; so as to make the road not only easier for carriages of burden, but safer and more pleasant to travellers, as well as more sightly: besides being better to be kept in repair, than an uniform descent; by reason of the flatter stages being checks to the surface water, and convenient places to get rid of it, without injury to the face of the road. But where such breaks do not occur, the line of ascent should be uniform; or as nearly so as the natural surface, or immoveable obstructions of the acclivity to be surmounted, will allow in the particular case.

Likewise in the setting out of these lines, the common level is to be set by an observation from the bottom to the top of the ascent (these points having been previously determined on, by the given circumstances of the general line of the road), or from station to station where a clear view cannot be had between the extremities; and the degree of ascent, thus ascertained, is to be marked with a pencil upon the instrument that is made use of for the purpose. And by this mark it is advised to trace a rough line along the face of the hill; in order to determine, with sufficient truth, respecting the proper breaks, or resting-places, that may be required; endeavouring to fix upon such natural breaks in the slope as are situated in, or sufficiently near, the general line of ascent. And that when this has been done, to ascertain, by similar observations, the exact angle of elevation, or degree of steepness of each rise, or length of ascent between the breaks, &c. by these means procuring an unerring guide, in marking out and forming the base or bed of the road; without the risk of incurring unnecessary labour and expence in doing the work twice over to bring it to the truth, or a state of suitable exactness.

But it is well remarked by Mr. Marshall, that the best services of the road surveyor lie in avoiding, not in surmounting hills. And that in a long line of road, between places of nearly equal elevation, this may often be done. There are instances of the most public roads going over the tops of hills, where lines of equal length might be traced along their bases; and the difficulty and danger of ascending and descending the steeps be avoided by such means.

Very much attention has lately been bestowed on this de-

partment of the road-maker's business, especially in the more northern parts of the kingdom; but much is still left to be accomplished, especially in the western districts of the southern parts of the island, where an attachment still remains to the original lines or directions.

And it is suggested by Mr. Beatson in the paper above alluded to, that the business of laying out the lines of roads may, in fact, be reduced to three simple principles; those of fixing upon the *shortest*, the *most level*, and the *cheapest* directions, for which, though apparently very easy of execution, from the frequent occurrence of circumstances that render it necessary to deviate from them, the knowledge and experience of the surveyor are found requisite. The first requisite from its being a straight line, is often necessary to be departed from in order to avoid the removal of expensive obstacles, such as hills, rocks, water, and morasses. The second is of vast importance, and should invariably be adhered to, if possible, even though the other two should, in a certain degree, be given up; for it is infinitely better to go a considerable way about to obtain a level road, than to go straight forward and be obliged to take an ascent; but it may, in some cases, be preferable to ascend a gentle rise, in order to obtain a good hard bottom, and a road easily made, than to go on a level through a swamp, or piece of water, which would require a much greater quantity of materials, be much more difficult to keep in repair, and occasion a great deal more expence. It is not the most hilly line to appearance that is always to be rejected as being the least level; for the steeper and shorter some hills are, it will be the easier to obtain a level road in that direction, by cutting down the summits, and laying the materials taken from them in the valleys or hollow parts, which, in many instances, may be done with great facility. And the third, or the least expensive line, is also frequently given up, in order to obtain one or both of the other two. It is therefore concluded, that much depends on the skill and ability of the surveyor, who, before he finally determines on a line of road, ought to make himself perfectly master of every part of the intermediate and adjacent country; nor should he rashly determine at once, but should examine repeatedly, over and over again, whether no other line would be better than that he first thought of.

And with respect to the parts or divisions of which a public road should consist, it is obvious that they should vary in some measure, according to the nature of the traffic or business which is carried on upon them, the situation in which they are placed, and the particular circumstances of the different cases. It is, however, contended by the author of the "Landed Property of England," that the plan and formation of all public roads should be the same; every public lane, or other sort of a public road, he conceives, ought, where the width and other circumstances will permit, to be divided into three travelling lines, namely: 1. A middle road of hard materials, for carriages and horses, in winter and wet seasons: 2. A soft road, formed with the natural materials of the soil, to be used in dry weather, to save the unnecessary wear of the hard road, and to favour the feet of travelling animals; as well as for the safety, ease, and pleasantness of travelling in the summer season: and 3. A commodious path, for the use of foot passengers, at all seasons. But in these cases, he thinks, modern practice has simplified too much. Instead of these three requisites of a public road, we generally find a parliamentary or turnpike road (away from the environs of great towns), consisting, simply, of one uniform broadway of hard materials; upon which horses stumble, and carriages jolt, the year round: while travellers on foot are seen wading to their ankles in

mud, or in dust, according to the state of the wind and weather. His notion of what the nature of a public road ought to be, is, that within the fences of a lane or road there should be a raised foot-path, a convex hard road, a soft summer road, and channels to carry off the water collected by the carriage roads; the foot-path being cut across, in proper places, to permit the water, which falls on that side of the middle road, to pass off freely into the ditch at that side, as well as to prevent horsemen from riding along the path; the opposite hedge-bank being perforated, to let off, into the other drain on the contrary side, the waters which may collect on that side of the lane or road.

And in regard to private roads it is contended, that where they are much used, as in such as lead from a village or other place to a public road, they should have a double carriage path, so that carriages may any where pass each other. But that for such as lead merely to a farm-house or a hamlet, a single line sufficiently wide to let a single or saddle horse pass a carriage with occasional dilations for carriages to pass in, are only in general requisite.

Form of Roads.—Further, in regard to the most appropriate form of roads, there has been a great difference of opinion among the persons engaged in this sort of work, some contending in favour of the *convex* form, while others are inclined to think the *concave* shape preferable in many cases; and still others, that they should be either made perfectly flat from one side to the other, with inclined planes longitudinally, or be *wholly flat* in every direction. But experience fully shews, that some degree of the convex form is necessary in almost every case, in order that the wetness and moisture may be discharged with greater facility, and of course the roads be preserved in a more dry state. And in speaking of this form of road, Mr. Beatson observes, that the rise in the middle is more or less according to the fancy or whim of the makers, but in general it is a great deal too much. This form is adopted on the idea, that whatever wet falls upon the road will run off towards the sides into drains made there for the purpose of receiving it. If the roads were a perfect smooth hard surface, this theory would, no doubt, he thinks, hold good; but in practice it is found not to be the case, for the wheels of carriages occasion so many ruts, and such a roughness on the surface of the roads in general, that little or no water can run towards the side-drains, however convex the road may be. It consequently lodges in those ruts, and every succeeding carriage, he thinks, the more easily makes them deeper, and works the water and materials together in such a manner, as very soon to render the road extremely disagreeable. This frequently happens, he asserts, even on roads that have been made most inconveniently convex, for the very purpose of keeping them dry; consequently, the convexity of a road has not the desired effect of preventing water lodging upon the surface. Besides, it is, he conceives, extremely inconvenient for all wheel carriages, and destructive to the road itself, by making the loading rest unequally upon the wheels, unless when going on the very middle of the road, for the lowest wheel will always bear the greatest part of the burden, and therefore will injure the road the more in proportion. If a cart or any carriage with two wheels is loaded, we will suppose, with two tons weight; when that cart is upon a level from side to side, the load is equally divided, and each wheel sustains the weight of one ton; but if that cart is going on the side of a convex road, there will perhaps be the weight of a ton and a half upon one wheel, and only half a ton upon the other, consequently the lower wheel, in this case, will do the road as much injury, as if the cart were loaded

with three tons upon a level, instead of two upon such a declivity. The proportion of weight upon each wheel, according to the declivity, will depend on the nature of the loading of the cart, for the higher the centre of gravity of the load is, the greater will that weight be on the lower wheel on the same declivity; and therefore a cart loaded with hay, straw, or wool, or any other bulky commodity, will be more injurious to a convex road, unless when on the middle of it, than the same cart loaded with the same weight of stone, lead, or iron, or any other weighty commodity which lies low in a cart: and nothing can be more injurious on such roads, than a stage-coach loaded with outside passengers. But the destructive consequences of allowing carriages to heel much on any sort of road are even visible, though in a small degree, he supposes, from the effect produced by a wheel going over a stone, or any hard substance lying in one of the tracks or ruts, in which case there will soon be a deep hole formed by the wheel in the other track, directly opposite to that stone or substance which raised the other wheel. Every precaution ought, therefore, to be used to prevent carriages heeling to one side on any part of a road. And he suggests, that the inconvenience, and in many cases the danger, of going on either side of a convex road, makes all waggoners, carters, coachmen, &c. keep always on the middle, by which, on such roads, there is seldom any other part used by wheel carriages, however wide the road may be; consequently, by the carriages being always confined to the same track, that part of the road soon gets out of repair, and requires a constant outlay of money to keep it in proper order or condition for being travelled upon. It is also added, that the method of forming and making the convex roads, in the first instance, appears to him very absurd. He supposes, that before any hard materials are laid on, the road is generally formed in somewhat a hollow manner, rounded below, in which there are drains, or ditches, on each side: also the footways or horse roads when made high enough. There are also sometimes called the summer roads, on account, he supposes, of that being the only season they can in general be travelled upon. The road forms a convex line, about ten or twelve inches lower at the sides of it than the footway and summer road. After being thus formed and prepared, the hard materials, mostly consisting of broken stones, are laid on, which, it is supposed, will fill up that space which is the hollow in a convex line, and when finished, the whole surface, from one side to the other, forms one convexity; the footways or horse roads being made a continuation of the same curve. And this is still with the idea, that all the water that falls on the road will run into the drains on each side. But let any person, in wet weather, take a view of a road thus formed, and he will find, that, in general, however great the convexity may be, the water will stand in every rut and every impression made upon it, especially if the road has been long travelled upon; that the stones on the surface are pulverized by heavy wheel carriages, and the wet earth from below worked up among them. Also where the road is but newly made or repaired, and the materials are sufficiently porous to let through the water, it will then lodge on the convex surface, in every impression of a stone or other uneven part, particularly at the sides, where it is dammed again by the footways, and thus the bed or foundation of the road is kept constantly moist, and of course it will very soon go out of repair. By this continual moisture the stones sink down into the soft earth, of which the bed of the road is composed, and this earth works up through the harder materials, and occasions all that dirtiness generally on the surface of roads in wet weather, although, perhaps, ten or twelve inches in thickness of those hard materials had

been at first laid over it. Sometimes, indeed, there are under-drains made through the footway, from the side parts, at every ten or fifteen yards distance, to convey the water into the ditches; but even this is not found to answer the purpose intended, for the intermediate spaces soon become so impervious, that the water does not pass through them to enter these drains, the wet earth being converted into a sort of puddle, resembling what is used, in aquatic works, for the purpose of preventing the moisture from penetrating through, and consequently it lodges in all the ruts and hollows on the surface, without passing off so quickly as should always be the case in such instances.

Besides this there is another manner of forming these convex roads advised in the Bedfordshire Agricultural Report, in which it is proposed to leave a hollow or vacuum, as it is called, in the middle, to deposit the hard materials in. The only difference that appears to be between this and the method described above, is, that instead of the bottom of this hollow being made convex, it is made flat, and also deeper. It is thought that this method is liable to the same objection as the former, perhaps even in a stronger degree; besides, it would require a much greater thickness of hard materials, which are very expensive, and those materials would be deepest or thickest in the middle of the road, where the wheels of carriages hardly ever go, consequently that part is not so liable to be cut up as the tracks in which wheels most generally run, and produce their greatest effect. Mr. Marshall seems, however, to think more favourably of this form of road, especially for wet weather, assuming it as a sound position, that roads, in general, which are intended to be travelled in wet seasons, should be *convex* or *shelving*, not flat or concave. It remains to determine the proper degree of convexity of the hard line of road; from the margin of which the dry-weather line ought to shelve gently to the foot of the hedge-bank; so that carriages may pass freely, and safely, from one line to the other; and in order that the rain-water which falls on that side of the lane may find its way, easily, into the channel prepared for it, which is, he conceives, for a wet-weather road, to be regulated by a variety of circumstances: as, first, by the materials of which it is to be formed: soft materials are most liable to be worn into ruts and hollows, and require to be laid up with a quicker descent for rain water, than hard materials, which require less elevation or rotundity of surface; and last of all a firm even pavement. Secondly, that a convex road in the face of a steep is to be laid up higher, with a given material, than one on more level ground, on which rain-water has no other tendency than to the sides; whereas in the face of a steep, it may have an equal or greater tendency along the line of road; and is liable to be caught by the slightest impressions of wheels; and thus to wear channels, as may too often be seen, from the top to the bottom of the hill. Even where the surface of the road is perfectly smooth, it may have twice the distance to run, before it reach the outer margin, that it has on a level. And thirdly, that the degree of convexity is to be determined, in part, by the width of the road; the materials and descent being equal. A wide road requires to be formed with greater sideway descent than a narrower one; which more readily frees itself from rain-water, inasmuch as the distance is shorter from the crown to the outskirts of the road in such instances.

But that the freeing of a road from rain-water is not the only object to be kept in view, with regard to its convexity: the ease and safety of carriages, and particularly those of burden, whose loads, being of light materials, are laid up high, require to be consulted. A carriage moves most freely, and with the least exertion of draft, when the load

lies evenly upon the wheels on either side. In proportion as the weight is thrown on one side or the other, the resistance is increased; especially on the road which is liable to impression. Hence the inconvenience of a highly convex road in the face of a steep; and hence the utility of breaks in long ascents, or such roads as are formed in hilly situations.

In fact, he conceives it evident in respect to convexity, that every part of a road should be equally and duly convex, —should be equally safe and easy for carriages of every description; otherwise it becomes partially worn; the more level parts only are used; the steeper being in a degree useless. Hence a road of even and due convexity is not only easy and safe, but may be formed of a narrower width, than one whose steep sides are neither easy nor safe to be travelled; and whose crown, only, is in use for passing upon. And on measuring different passages of roads which appeared to lie in the most desirable form, and taking their convexity, or the elevation of the crown or middle of the road above the base line, he has found that roads of twenty feet in width rise about ten inches: namely, one inch in every foot, on either side. And he is of opinion that this result may be taken as a general guide in forming roads: this middle degree of convexity being liable to be altered according to the width of the road, the nature of the materials, and other circumstances which have been stated already.

And concerning the second or concave form of roads, Mr. Beaton thinks that it is quite the reverse of the common form, being lowest in the middle, where other roads are generally made highest. By differing so widely from the common practice, and the general opinion of road makers, one would at first be almost inclined to suppose, that so singular a practice in forming roads could only proceed from a desire or propensity to differ from the rest of mankind: but when we are told that the late celebrated and ingenious Mr. Bakewell was an advocate for this form; that the road by his farm of Dishly, and that through Mesham, in the same county, are both upon this principle, and in much better order than the roads found about them; likewise that the road through Bredon, made under the direction of Mr. Wilkes, is of the same form, and is said to be better now than ever remembered before, and kept in order at much less expence:—when we consider these well authenticated facts, supported by such respectable evidence, we naturally conclude that the reasons for adopting this uncommon form of road, are founded on something more substantial than mere whim and caprice; and consequently deserve to be more fully investigated. This writer states, that he has not been able to learn the manner of forming these kinds of roads before the hard materials are laid on, but, when completed, he understands the form is something similar to that of a paved street, with a drain for the water in the middle. The whole width of the road is divided into three equal parts, or nearly so. The sides are made quite flat. The middle division has a gradual but small descent, or concavity, from each side to the middle part, which is the middle of the road. This concavity has also a small descent lengthways, made on purpose, if not declining naturally, sufficient to carry off the water to proper outlets. In the middle division the best and hardest materials are laid. The direction of Mr. Wilkes, as stated in an ingenious paper, in the first volume of Communications to the Board of Agriculture, is, that when the fall is one foot in 150 or 200 feet forward, the fall from the sides towards the middle ought to be 15 inches in 20 feet. When one foot in 100 to 150, to be 12 inches. One foot in 30 or less, to be even the whole breadth.

Where the width of a road is 60 feet, one foot of fall to each 40 feet in length of the road. Twenty feet from the sides towards the middle, to have nine inches of fall.

The inner 20 feet to be flat.

And Mr. Bakewell's idea, he is informed, was, that water, where it can conveniently be applied, should frequently be let run upon this concave part, in order to wash it quite clean; for it is always observed, where a small stream of water comes upon a road, that part, if the bottom is good, is generally firmest, and hardly ever gives way. To have a command of water, therefore, to flood the road at pleasure, he thought would be of great advantage in keeping it in order. And the other useful properties attending a road of this form are the following: There are three parts of it on which wheel carriages may go, without heeling to either side; on the side divisions, and also on the middle division, when the horses walk in the lowest part. This is certainly a material advantage, being much more easy for the horses and less injurious to the road. By carriages using indiscriminately these three tracks, all parts of the road will wear more equally and for a greater length of time; whereas in the convex roads, there being only one part, namely, the middle, on which carriages can go without heeling, that part only is most generally used, and consequently soonest gets out of repair, which is a great inconvenience in such roads.

With respect to flat roads sloping longitudinally, the advocates for them observe with good reason, that by being flat or level from side to side, the pressure of wheel carriages will be more equal, the friction less, and all parts of the road may be travelled on with the same facility; consequently it will wear more equally, be easier kept in repair, and require fewer materials for keeping it up. But notwithstanding such advantages are deserving of attention, it must seem to those unaccustomed to such a form of road, a difficult matter to keep it sufficiently dry, or free from the stagnation of water upon it. But from its having been observed that the ruts made by the wheels of carriages prevent the water running to the sides of convex roads, it is proposed that roads of this form should have in every level part gentle slopes, sufficient for water to run along, which, supposing them to be one foot in fifty, would hardly be perceptible. On these slopes, or inclined planes, the ruts made by the wheels of carriages would promote the water running off, by forming so many little channels or conductors for it to run into the lower part of these slopes, from whence it must be properly conveyed away. By this plan such roads will be much more easily kept dry than the common roads usually are or can be from the nature of their construction.

And farther, in regard to the wholly flat form of roads, the reasons given for them are nearly the same as stated in support of the last, only that as there are few parts of a country so perfectly level, for any considerable distance, that water will not run either one way or another, it is consequently unnecessary to be at the expence and trouble of forming those slopes or inclined planes recommended in the preceding form; but that proper outlets should always be kept clear at every hollow part, and if the road should in any place be quite level, a shallow cross drain, that will occasion no impediment to carriages at every 50 or 60 yards distance, or nearer, will keep the road sufficiently dry.

And it is from these statements concluded by Mr. Beaton, that the main objects sought after are, 1. To keep the road always as free from moisture as possible: and 2. To construct it in such a manner, as to render the draft or communication easiest, at the least expence. In these are

comprehended all the requisites necessary to form a complete road. To attain them in the best manner is therefore the important point. Four different methods have been stated, each of which has its supporters. The arguments in favour of each have also been shortly mentioned, which will shew that their main object is the same, unless perhaps the idea of watering the concave road may be considered a deviation from one part of the general rule: but as that is proposed to be done only to wash the road occasionally, in case it becomes dirty or flushy, it cannot therefore be considered in that light in any respect whatever. But from these modes of constructing roads being in some measure unsatisfactory, he is induced to offer a new theory on the subject, which is founded on the knowledge of the stratified nature of the earth. It is however only given as theory, having never, he believes, been subjected to the test of actual practice. It is observed, that every person who has paid the least attention to the structure and formation of the different strata of the earth, must have seen that some of these strata are of so close a texture as to be impenetrable to moisture; others again are so porous, that water will easily run through them in any direction, till it meets with some obstacle, or finds a vent. Of the first sort some are less dense, and of the latter some less porous than others, consequently as they partake more or less of these qualities, the water or moisture will the more or less quickly penetrate through them. But in order to shew this more clearly, and apply the principle to the construction of roads, he supposes the section of a hill or eminence composed of a number of strata. If the upper stratum or surface soil is of a porous nature, it is evident that any water which falls upon it, will penetrate through to the stratum below, where, if it cannot go farther, it will glide along the surface till it finds a vent at the bottom of the hill; if the second stratum is hollow, and continues on towards any depression in it, the water will lodge in that hollow, and form a sort of pool or bog, as is sometimes observed on the tops of hills; but if in this hollow place there is a communication with the porous stratum, no water will lodge there, but it will penetrate through and glide along the upper part of the dense stratum below, till it finds a vent on the side or at the bottom of the hill, as before. And by the above it will also appear, that if the uppermost stratum is of a close texture or clay, any water falling upon it will not only lodge in the large hollow, but in the smaller ones, and in all the other irregularities or concavities that may happen to be upon the surface. Hence, also, it is evident that in order to keep dry the surface of any such piece of ground, it matters not of what shape or form that surface is, or whether it is convex or flat, provided there is a communication with some under stratum, sufficiently porous to carry off the water below; but it is of some consequence the form of the upper part of that stratum upon which the water is to run, for the smoother it is, the water will of course the more easily flow away, and be discharged from it.

It is easy, it is supposed, to apply these principles in the forming of roads in the following way: when a new road is to be formed, let it be done in the first instance nearly in the usual manner, with such materials as are on the spot, and the nearer the quality of these approaches to clay, so much the better. Instead, however, of forming it convex, as is generally done, let the lines on either side from the middle be quite straight, and meet in an angle or ridge at that part or the middle of the road, having a slope from thence to each side, of about an inch in a foot. There are to be made small drains for the more easily conducting away the water that may be collected at those places. The road, being thus

formed, must be allowed to harden and settle for some time before any other materials are laid on, great care being taken, while in that state, to let no carriages or cattle upon it, and it should be rolled with a long wooden roller, that will reach at once from each of the sides to the middle. This roller should be loaded with a box of stones to make it sufficiently heavy, and that it may be the more portable when that box is taken off; and it may be so contrived, that by changing the horses from one side to the other, there will be no occasion to turn the roller, in order to make it roll the same space over again. Being rolled in this manner, will consolidate the materials composing the ridge of road, and prepare it for receiving those to come afterwards, for it is a most absurd practice to lay hard materials in the common way upon this first form or basis of a road, before it is sufficiently firm to bear them. When thus formed and properly settled, the next step to be taken is to imitate the works of nature in dry soils as nearly as possible, by forming a stratum penetrable by water, composed either of sand or sandy gravel, or any other substance easiest to be got, that is sufficiently porous to admit water to pass through it. This stratum should be laid quite level, and extending from one side of the road to the other, filling up the small drains also on the sides. Over this are to be laid the best materials that can be got for completing the road, consisting either of stones broken very small, or of the best gravel. This coat of hard materials need not exceed above six or seven inches in thickness, which being much less than is commonly used, will be a considerable saving; and it may even still be less, if the directions hereafter given are strictly attended to. If this covering consists of broken stones, they should afterwards be laid over with sand or fine gravel, when easily procured, so as to fill up all the cavities betwixt them. The sand or rubbish from a freestone quarry is excellent for this purpose, providing there is no mixture of earth in it, which should be carefully guarded against in every step taken after the road is first formed. These finishing materials being properly laid on and smoothed with a rake, the whole should now, before any carriages or horses are admitted upon it, be well rolled with a heavy iron roller, divided in three parts for the purpose, the two hind divisions of the roller being large, the front or middle division smaller, to the framing of which the shafts are fixed, and so contrived, that it turns in the manner of the fore-wheels of a waggon; there is a box for holding stones to increase the weight when necessary; but in adding this weight, it must be observed to lay about two-thirds of it over the two large parts, and only one-third over the other, otherwise the pressure will not be equal. Iron rollers are sometimes made in three parts, as above, but being all in a line, and close together, they are apt to be choaked by gravel and small stones, which cannot happen in the construction here recommended. It is contended, that if such a roller were generally used upon roads, especially when newly made, it would save a great deal of expence in repairing them; for it cannot be expected that any new road will immediately bear wheel-carriages, or continue long in repair, when composed entirely of loose materials, without the smallest pains being taken to consolidate them together. Frequent and heavy rolling would therefore produce the most beneficial effects, and would tend very much to keep the road free from deep ruts and holes; besides, there is nothing could contribute more effectually to promote and preserve firmness and solidity, two qualities without which it is impossible any road can, with propriety, be called a good one, or have the necessary degree of solidity and firmness.

The advantages that would result from this mode of con-

struction would be various : by being level on the surface, every part of it is equally commodious for carriages, consequently it will all be equally travelled upon, and the deep ruts so frequent in other roads, will almost entirely be prevented. It will therefore be much easier kept in repair, and, if properly managed at first, will be made at less expence than the common roads, especially in a sandy soil, or where sand or gravel is easily procured. The draft will be much easier on such a road. And one very important advantage is, by having an under-stratum through which the water can penetrate, and the cavities among the harder materials being filled with the same porous substance, no water can ever lodge on the surface, nor can it ever become so dirty as other roads are in wet weather ; all the water that falls on the surface, unless perhaps in very heavy rains, being conducted away underneath and in every part. And it may be added, that from the small drains on each side of the road, cross-drains should be carried through the fences, provided the level of the ground will admit of it, at the distance of every ten or fifteen yards. These cross-drains may be made of wood, with about an inch bore, or of stone, if preferred.

It would be of great advantage to this sort of road, as well as to every other road where the ground is inclosed on each side, that the fences should be sunk towards the fields, and the water be conducted through to these sunk fences, instead of the common method of leaving large open ditches and drains on each side of the road. It must also be particularly attended to, that on all sloping roads on a declivity, where the water is apt in heavy rains to run upon the surface, or at the sides, that it ought never to be allowed to run in the same direction more than ten or fifteen yards, but at that distance to be conducted away to a side into the main drains. It will then do little or no harm, as it can never increase beyond a very weak stream ; but if it is allowed to run one hundred or two hundred yards, it will probably be increased to such a size before it reaches the bottom, that it will wash away a great deal of the materials, and may besides very much injure the road or fences on each side of it, which would be highly disadvantageous in many respects. Besides, it is suggested, that a road formed on this plan need not be quite so wide as roads in general are made, for the whole surface of it will be in use from one side to the other, and therefore from twenty to twenty-four feet wide is quite sufficient, unless near populous towns or extensive works, where great numbers of carts or waggon are employed. And in the interior parts of the country, twenty feet in width will answer every purpose required. He has observed in several places, where the roads have not been above eighteen or twenty feet wide, and properly made from side to side, that they were in much better condition than the neighbouring roads, from thirty to forty or fifty feet wide. On these wide roads, formed in the usual way, there is seldom more than eight or ten feet in the middle of them generally made use of ; the remainder one on each side being occupied by heaps of stones, scrapings, and other rubbish, which, although they may partly be of use sometimes in repairing the roads, ought on no pretence to be allowed at all times, or at any time, to lie there ; such rubbish being not only disgraceful on the sides of a public highway, but even dangerous, particularly in the dark, for either carriages or horses ; besides having various other disadvantages arising from the growth of weeds, and the dissemination of their seeds.

But in respect to the most proper and best form of the roadway of narrow lanes, as those leading from village to village, in reclus situations ; where bridle roads, or packways, have been so far opened as to admit carriages ; or

though the whole width of the lane may not be more than eight or ten feet, it is remarked by the author of the treatise on "Loaded Property," that on such a narrow space, a whole barrel, or convex road, cannot easily be kept up. If raised, it presently wears into a middle track, and two wheel-ruts, with foul drains on either side of them ; and becomes, in wet weather, a dirty trough, which is unfit for either carriages or horses, and in which a foot passenger has not where to set his foot. But that provided such a lane be thrown into a shelving form, resembling half a barrelled or convex road, a greater width of travelling road for carriages and horses will be obtained ; ruts will not be so liable to be formed ; the whole of the water of rains will be thrown on one side ; while the other will afford a comfortable walking path at all seasons. And this, it is added, is now no longer merely a probable, but a tried improvement. Lanes, ten, twelve, or more feet wide, have been strikingly improved by it. And it is further suggested, that when water, in a wet season, is apt to ooze out of the banks on the upper side of the lane, a narrow channel is to be cut, to prevent its overflowing the road : or, in forming the bed of the road, the inclination may in some cases be reversed ; so as to throw the drain on that side of the lane from whence the spring water issues : thus the same drain will serve for the spring and the rain-waters. And it is added, in regard to this semi-convex form of road, that it is applicable, not only to narrow lanes, but to the sides of hills ; where the road, as it generally ought, is conducted sidelong, not directly, up the slope. By this form of the road, the whole of the water which falls upon it will be got rid of, without inconvenience or expence. And the bed of the road, for this purpose, may be made narrower than for a full convex road ; a circumstance which, in some cases, may become a saving of much expence. The upper side of a road in this form being nearly level, and firm to the foot of the steep, would be chosen by ascending carriages ; while the lower side would acquire a loosened surface, and be used by laden carriages going downward ; and while a raised foot-path, on the lower margin, would be a secure guard, and a relief to the apprehensions of timorous travellers.

But in relation to the width of public roads where a blank is given, it should be regulated, Mr. Marshall says, by their publicity, as it is compound folly to make a road wider than its use demands. He supposes that there are few roads, even near populous towns, that require a greater width than about thirty-three feet. But every public road, under common circumstances, should have a line which is travelable at any season, and of ample width to permit two carriages to pass each other with freedom and safety. This ample width let us set down as one statute pole. In deep clayey districts, where hard materials are difficult to be procured, a single road, of half a pole in breadth, with dilations at proper distances, to let carriages pass each other, may, in many reclus situations, be advisable. This regards the breadth of the winter road, for carriages and animals of burden. But that the width of a public lane requires a more enlarged view. On the plan offered, it is to contain, not only a wet-weather road, for carriages and horses ; but a summer road, and driftway ; as well as a foot-path, which may be used in any season. He observes, that in many parts of the greatest public roads across the kingdom, the lane is not more than twenty feet wide. But this being filled with hard materials, from hedge-bank to hedge-bank, carriages alone seldom find any inconvenience in these narrow parts. But where carriages, and large droves of cattle or sheep meet in them, stoppages are unavoidable, and great inconvenience is of course sustained.

And it is thought, that the width of the *driftway* ought, like that of the hard materials, to be guided by the publicity of the given road. In a great public road, it should certainly be wide enough to let two carriages pass each other, or one pole in width. But in one of less publicity, or where the existing lane will not admit of that width, a single carriage path may suffice; as this being a continuance of the width of the hard road, no difficulty in passing can be experienced, it is supposed, from it.

But the width of the *foot-path* and the ditch may vary from half a pole to ten feet.

It is therefore concluded, that on these premises, the width of the lane of a great public road, near a populous trading place, ought to be fifty-nine feet and a half; and that of a common market-road, thirty-three feet. And these widths, without any previous intention, come out nearly the same as those directed by act of parliament, for the lanes of turnpike roads and highways. A great error in the act, however, is, that the lanes of all turnpike roads, shall be sixty feet wide: thus incurring a serious waste of land; and creating great nuisances; which green lanes ever are to the occupiers of adjoining lands. He from this suggests, that where existing lanes are wider than all the desired conveniences require, slips should be sold off their sides, and be laid to cottages, or to the adjoining inclosures; having recesses here and there, in which to lodge materials. It has long appeared to his mind an evident position, that every part of a public lane should be used; and consequently that no part of it ought to be a nursery for weeds, or an unprofitable common pasture for starving stock. Still he remarks, that a wide lane has its advantages; especially in a low close situation. It gives freer admission to the sun and air than a narrow lane, and the road dries more quickly. And further, that by permitting a more forcible current of wind, the pulverized materials, or dirt of the road is, in dry seasons, carried off in the state of dust; leaving the useful materials undisturbed. And it is highly proper to place the principal line of road in the midway of the lane, that it may be the most effectually exposed to the agency of the sun and wind.

Mr. Beatson even suspects, that, in the whole kingdom, thousands of acres of fertile lands are lost to the public, merely by making the roads so much wider than there is any necessity for. In the vicinity of large towns, they should have an ample width, as 30 or 40 feet; or, in some cases, considerably more, as near the metropolis. But the practice of making them 40 or 50 feet wide, as is sometimes the case, through a thinly inhabited part of the country, or near the most pitiful villages, where even 20 feet would be sufficient, is, he contends, a mere waste of ground for no purpose, and occasions a very great additional expence in making such roads, which certainly might be avoided. Supposing the medium necessary width of road to be 7 yards, or 21 feet, and that the medium width now made is 11 yards, or 33 feet; this is, upon that supposition, 4 yards wider than is necessary; which, in every mile, is a loss of 1 acre 1 rood and 2 perches: and supposing there are 5000 miles of such roads in the whole kingdom, there is a loss of more than 6300 acres, which, if estimated the same as the improved value of the waste lands, at 27s. per acre, and at 30 years' purchase, would produce 255,150l.; a sum which, if laid out in improving the roads, and making easy communications through different parts of the kingdom, would be of the greatest public advantage. And it is evident, that where they have the width stated as necessary by the first of the above writers, the loss sustained in this way must be still greatly more considerable.

Mr. Marshall thinks, that in the operation of forming roads of the public kind, the first business of the road-surveyor is to examine the lane, or other site of the intended road, in every part, to ascertain whether offensive waters lodge beneath it, and whether quicksands or land-springs break out in a wet season, in which this examination is requisite to be made. If defects of this kind be found, effectual subdrains are to be run up to them from the ditches or side-drains of the lane, or other site. And that the next operation is to adjust the surface of the site; to strike off the protuberances, and fill up the hollow parts; and thus, in ordinary cases, to mould it to the first proper form, or according to some of the other forms that have been mentioned; the foot-path and the higher side of the soft road being raised with the earth which is required to be taken off the bed of the hard road, whose base or foundation ought to be formed with peculiar care. Every part is required to be firm and sound; dry earth or hard materials being rammed into every hollow and yielding part. It is suggested that the first form is adapted to firm binding materials; to such as acquire, by wear, a repellent surface, and shoot off the waters that fall upon it; not to those which are loose and incohesive, yielding to pressure, absorbing rain-waters, and conveying them down to the base or bed of the road. These require a flat or a convex bed, free from obstructions on either side, so that the absorbed waters may effect their escape at the base. And that on this firm and level bed the largest of the hard materials are to be laid; next, those which are more finely and evenly broken; and, lastly, a covering of still finer materials: to assist the roller in giving sufficient firmness to the surface, and to render it immediately capable of being travelled upon.

But in regard to the proper materials for constructing roads with, Mr. Marshall thinks that although every district may be said to have its own material, and often without choice or alternative, yet there may be instances in which useful materials are overlooked or disregarded. And that in some parts, particularly in Lancashire, large paving stones are in common use; some of the more public roads being rough pavements, resembling the streets of ill-paved towns. But that in the northern, and some of the midland provinces, broken quarry stones are the ordinary road material; and that, taking the kingdom at large, they are the most common material. But in the southern and western counties, flints and other hard field stones, gathered off ley grounds, are in common use; and in the neighbourhood of the metropolis, and in other parts of the kingdom, sharp flinty gravel is a favourite and valuable material. In many parts of England, smooth, water-worn, pebbly gravel, collected on the sea-beach, and in river beds, is used; and if the pebbles are of a hard texture, and be properly broken, to make them bind, or unite firmly together, a good road may be made of this material. In some cases, sand and silt, or fine sea-sand, have been employed with success.

It is likewise added, that the artificial materials of roads, which he has met with, in quantity, are the dross and cinders of iron and copper works; and burnt clay, (burnt as bricks in heaps,) which in a clayey district, destitute of other materials, and where fuel is cheap, may be found a valuable substance for the purpose. It is suggested by Mr. Beatson, that in a sandy soil the roads may be made on the new construction, he has already recommended, with the greatest ease. In such a soil, there will be nothing more to do than to level the surface properly, fill up all the hollow parts, roll it well with the long wooden roller, and lay on the materials intended to finish it with, in the manner di-

rected, and then roll it with the heavy roller, as has been advised above.

But in cases where the soil consists entirely of a deep loose sand, the best and easiest way to make a lasting road is, to form it to the width intended for the hard materials, and then to let a channel be dug at least 18 inches in depth, and about the same width: let these be again filled, and firmly built up with strong turf or clay, or any other solid substance that will prevent the materials to be laid on the road from spreading to either side; openings being left at every 10 or 15 yards, to let the water that falls on the middle part of the road more easily through. Where the form of the ground requires making up, a little wall of the same nature, instead of digging a channel, may be built on each side, nearly as high as the surface of the road is intended to be. These will prevent the hard materials laid on from spreading, which is the principal cause of roads made in such soils giving way in so short a time; and these materials will not be so liable to sink into the sand, if it is properly rolled before they are laid on, as well as at different periods after it is finished. And if there be a fence on each side of the road, and materials can be spared to cover it from side to side, there will be the less occasion for the little walls; as these are only intended to keep the hard materials within the bounds prescribed, in case it is not judged proper to lay them, the whole breadth of the road. Where, however, those walls are thought requisite, the spaces, by being covered with a little gravel or freestone-sand, will make very good foot-ways or horse-roads; but in a road finished in this way, there will be no occasion for horse-roads distinct from the main road, as the whole, if kept in proper order, will, he supposes, be sufficiently smooth and safe for horses, or even foot passengers, to go upon at any time. In speaking of the making of roads through a clayey soil, it is remarked that those formed in such districts are in common the most unpleasant of any, chiefly on account of proper precautions not being taken to prevent the water lodging on the surface; sometimes, perhaps, owing to a want of proper materials, such as stones or gravel: but he has often seen the very worst of clay roads, even where no such excuse could be given. And that it seems hardly ever to have occurred to those who had the direction of such roads, that sand, properly applied, would in a great measure remedy all the defects complained of; and there are few parts of a country where sand of some sort, or freestone-rock, or sandy gravel, may not be obtained by some means. In certain situations it may, no doubt, be more expensive and difficult to procure such materials than in others; but these are local advantages, which road-makers must lay their account with. But the excessive inconvenience of bad roads, the expence occasioned by the tear and wear of wheel-carriages and harness, the risk of dislocating the limbs of horses, together with many other disadvantages, ought to stimulate all concerned to exert their utmost endeavours to make roads good, and easily passable, be the difficulties what they may, that stand in the way of them.

It is hinted, that in such places as where no hard materials can be got, if the road were formed nearly in the same manner as that first noticed, the evils complained of might probably soon be remedied. The clay should be excavated, so as to form a ridge in the bottom of the excavation. There should be small openings or drains at every 10 or 15 yards, or at every hollow place, to conduct away the moisture into the main drains. If this excavation is then filled with sand, or any other porous matter easiest to be got, and finished as formerly directed, there is no doubt but the road would soon become as good as could be wished

for. Something similar to this he has known put in practice by a very ingenious gentleman in Cheshire, on whose estate, being a strong clay soil, the roads were so excessively bad as hardly to be passable. He dug away the surface of the road to the depth of 12 or 14 inches, and having the command of plenty of sand, he filled up the excavation therewith, and covered the whole with gravel; by which means he has now made, so far as completed in this manner, as pleasant a road as one could wish to travel on. He is not certain if he left the bottom of the excavation with a ridge in the middle, as here directed; but he is clear this would be an advantage, as well as the outlets at certain distances, to let away the water.

And in constructing roads through boggy or morassy soils, it is advised, after proper steps have been taken, to drain off as much of the water as possible, by deep ditches or drains within the fences, if inclosed, or intended to be inclosed, on each side. These drains should be cast at least a twelvemonth before any thing else is done towards making the road; for if the place is very boggy, it will be found to subside considerably after the water is drained away; and some parts will subside more than others, in proportion to the depth of the mossy soil, and to the quantity of water lodged there. Those parts will, therefore, be the better seen the second season than the first. All hollows or irregularities should then be filled up and levelled, either by taking from the heights and filling up the hollows, or by some other proper materials nearest at hand. In either case, the surface sods should, with a push-plough or paring spade, be carefully pared off the heights to be lowered, and also off the hollows to be filled up. These sods should be laid aside, till those places are brought to their proper level, and should then be laid on again. This will make the whole surface of an uniform toughness, which would not be the case where the sods are not laid on in this way. After this has been done, the breadth of the intended part for receiving the hard materials should be marked off; then let that part be covered with sand, or such porous substance, as before recommended, to the thickness of at least 10 or 12 inches. Then roll this, and finish it as already directed; and there is no doubt but a road made in this manner may be as good through a moss as in any other situation. This he speaks of from experience, having seen the most pleasant roads made in this manner, through mosses formerly thought impassable. When the moss is too soft to admit horses upon it, the sandy stratum may be rolled by men, the weight of the roller being regulated by the stone box, according to their strength. Sometimes the rolling is altogether omitted; but it is much better to roll, when practicable. It is added, that there are other methods of making roads through mosses; as by laying a foundation of broom, furze, or heath, and then the hard materials above them. But sand is greatly preferable, where it can easily be got, and when the track of the road is properly drained, as it always ought to be, before any thing is laid upon it with a view of making a road. These principles and directions are, it is said, equally applicable on all other sorts of soil, with trifling variations, according to the peculiar circumstances of the cases.

And it is supposed, that in the above cases the roads were formed where the scite or track was nearly level from one side to the other; but there are other situations, such as when cut or formed on the sides of hills, where some other precautions become necessary to be attended to. In these cases it is observed, that in making them it frequently happens that the excavation affords a sufficient quantity of materials for the purpose; and the part cut out

of the solid very rarely requires any covering laid upon it. This, however, depends on the nature of the soil. If the whole breadth of the road is formed from the solid, and that is sufficiently hard, no extraneous materials will be necessary; but if the soil is a compound of clay, or of a soft nature, the above rules and regulations must be had recourse to. And that where the parts are made up from the excavation, they ought to be formed considerably higher at first than the other parts, as they will naturally subside for some time afterwards, and the hard materials should not be laid on till they have sufficient time for that purpose, which may be greatly expedited by rolling; and it should be observed, that it is much better to be obliged to lower those parts to their proper level before the materials are laid on, than to be under the necessity of making up any of them at the time. And further, that where the hill is of a considerable height above the road, a good deal of water will sometimes come down. In this case it is in general better to intercept that water at some little distance from the side of the road, than to allow it to run down the face of the bank. If allowed to run down this face, it will very soon moulder it away, especially in frosty weather, and will always choke up any drain that may be made, whether covered or open; for if covered, the earth that moulders down will in a short time become so close, that water will not get through it to the drain before it runs off upon the road; and if open, it would be extremely difficult and troublesome to keep it clear. In this case, by intercepting it about four or six feet from the brink, and conducting it away to the most convenient outlet, it would be much easier to keep the road dry. If the face of the bank be irregular, the water may still be conducted away, by making the drain recede from the brink at such places, and keeping the course always at a proper level, or it might, he supposes, be let off at every hollow place by small recesses faced up with stone, or by wooden spouts sunk upright in the bank at every such hollow; to conduct the water from the upper drain to a cross covered drain below the road, by which it may be carried away at the lower side, without any injury being done to the road. And it is advised, that in the forming and making of these, as well as all other roads, the preventing of any water running on them, except what falls from the clouds, should carefully be attended to. Where this cannot easily be done, and where it is necessary to allow a stream to run along the side of a road, the drains or ditches which, as before observed, should be within the fences, should be made of a proper size accordingly, as the small drains filled with sand or gravel, as already recommended, are only meant for such roads as can have no extra water coming upon them in this way.

But in respect to *private* roads, the nature and manner of laying them out has been already noticed. And in respect to the method of forming them, Mr. Marshall says, it is the same where strong cohesive binding materials are made use of, whether in a lane, or across open ground. The mode he advises is to form a receptacle for such hard materials, twelve or more inches deep; either by digging to this depth beneath the natural surface, and carrying off the excavated soil; or to half the depth, disposing of the soil raised in the operation on each side of the receptacle; so as to elevate the general surface of the road above that of the adjacent ground. And in this receptacle deposit the materials; leaving the surface either in a convex or a semi-convex form, as the turn of the surface of the ground to be travelled over may direct: the margin or margins of the road, at which the rain-water is to be collected, being

left a few inches beneath the adjoining sward. But that in forming roads of every description with sand, loose gravel, or other incohesive absorbent materials, which imbibe the rain-waters that fall on them, a receptacle of that kind is altogether improper. Such materials ought to be laid on a level or an elevated surface; and a shallow drain to be open on either side, for the absorbent waters to filter into; thus preventing a furchase, and freeing the surface entirely from collected moisture, which would be highly injurious to it. And it is here added, that the surface of a road which is formed of well-broken stones, binding gravel, or other firmly cohesive materials, and which is much used, presently becomes repellent of the water which falls upon it; no matter as to the basis on which they are deposited; provided it is sound and firm enough to support them. And that where the situation is low and the land of a moist retentive nature, a deep drain on one or on each side may be proper to give due firmness and stability to the base. Such drain, however, is not to be sunk close along the margin of the hard materials, to deter horsemen and carriage-drivers from coming near it, but a few feet distant from it; so that every inch of the hard road may be used with equal pleasure and safety, and a commodious driving and walking path be formed between the road and the drain; proper channels being cut across it, in order that it may be kept properly dry. And further that in a dry situation, as across a gravelly or stony height, little more is frequently required than to remove the surface mould, and lay bare the rock or the bed of gravel beneath it; and then to give the indurate base a round or a shelving form, as the lying of the ground may require. In this way a travelling road may be made, and kept up at one-tenth of the expence incurred by the ordinary practice in this case; which is to gather up the surface soil into a ridge, and on this soft spongy bed to lay coat after coat of some hard materials, fetched perhaps from a distance! at much expence for the purpose.

But in addition to the above sorts of roads there are still others, which require some art to form and keep them up in particular situations; these have the denomination of carriage and horse-tracks, and are described under these different heads.

Methods of Repairing Roads.—It is noticed by the author of the "Landed Property of England," that this is a business that incurs a heavy expence on landed property, and of course requires the peculiar attention of the proprietors and managers of land. And in the paper mentioned above it is observed, that where the funds of the parish will admit, which would generally be a saving, that proper persons should be appointed in them, or have the charge of a certain extent of road to see where any part is giving way or getting out of order, and to direct their immediate repairs. Also to take care that no water stands in the hollows or ruts upon them. And, that the summer season is the best not only for making, but for repairing roads, nor ought they on any account to be touched in winter, unless to give a temporary aid to some sudden breach that is perhaps almost impassable, or to let off any standing water. Yet nothing is more common than to see a number of labourers employed on the highways in winter, when the days are short, and but a few hours labour can be obtained of them. Indeed so little attention is there often paid to repairing the highways, that sometimes old infirm people are employed for the purpose, as if repairing roads were a sort of trifling bye job, merely for the employment of paupers, or lame, miserable objects, who can get no other means of subsistence. And Mr.

Marshall thinks, that in this sort of work, the best service of the surveyor is to keep their surfaces smooth and even; so that rain-water may find a free and ready passage to its proper drain. Ruts and hollow parts are to be filled up, level, or even with the general surface, as often as they are formed, and perfectly free from water. This attention is more especially requisite to a new made road, whose bed and foundation are not yet fully confirmed. But in every case, and at all times, a solicitous regard is due to this most important, yet most neglected part of road surveying. Much expence of materials and labour may thereby be saved, and the great end of road-making be fully obtained; namely, that of rendering the road in all seasons easy, safe, and pleasant to the traveller, as well as easy in the conveyance of all sorts of articles. Besides, he conceives, that in this operation, as well as that of making new roads, very much depends on breaking the materials evenly. For, by doing this, the wear of the road becomes regular. Where the heads of large stones rise above the general surface, they become obstacles to carriages, and stumbling blocks to horses; beside their tending, by the jolting motion which they give to carriages, to indent the surface on either side of them, and thus to increase the roughness, and hasten the decay of the road. It is added, that by the law of gravitation and the action of wheel-carriages, a pit or hollow place in the surface of a road is made deeper every time the wheel of a carriage passes through it. The periphery of the wheel acts as a chissel, and in falling into the hollow receives an impetus or acquired force in addition to the actual weight it is loaded with; and, in addition to this, an undue proportion of the general load is, by placing it out of its upright posture, taken from the upper and thrown upon the lower wheel. Likewise hard protuberances, beside being dangerous or disagreeable to travellers, whether on horseback or in carriages, are injurious to a road, as being the causes of pits and hollow places in its surface. Every hard protuberance, as the point of a stone standing above the general surface of the road, or a large stone lying loose upon it, is productive of four impressions: namely, two, by throwing additional weight upon the opposite wheels (going both ways), and two more by the impetus or acquired force of the wheels (passing both ways) in falling on the surface of the road. He therefore considers it to be the first duty of the surveyor, not only to fill up the ruts and hollows, from time to time, but to pick out or to crush with a heavy hammer the stones, whose tops rise above the general surface; as well as to gather off those which lie loose upon the road; the latter being an operation that is readily performed, yet frequently neglected, and in some places to a shameful degree, especially in the northern parts of the island.

And in respect to the sizes most proper for road-stones it requires much latitude. Not only the intended use of the road, but the nature of the material is to be considered. A road for broad-wheeled carriages of burden, only, may be made of larger stones than one for narrow wheels. And hard stones require to be broken smaller than those which more readily wear down, and form a travelling surface. For when once the surface of the materials becomes united and cemented together, and its rock-like texture established, the stones that are crushed, and the smaller fragments which are splintered on, in wear, serve, he supposes, to incrust and bind together the stratum of stones which lie next, in succession, beneath: especially if proper attention be paid to the irregularities of wear, and to bring back the surface, wherever it is requisite, to its original evenness of convexity where that form is adopted:—so that it may, in

every part, act as an arch, and may be able to resist, with the greatest firmness, the weight with which it may be impressed. It is, however, to be observed, that, in forming and repairing roads with stones of size, a considerable part of the expence arises from the labour of reducing the materials; and, in consequence, the smaller they are broken the greater becomes the expence. Thus, on ordinary occasions, is a serious consideration. Hence, in constructing and repairing common roads, it is advisable, instead of reducing the surface stones to small fragments with the hammer at a great cost, to cover them with materials that are already reduced; as the rubbish of stone quarries, soft stones, or gravel, or the scrapings of the road to be repaired. Such cementing materials being washed and worked down by rains, and the action of carriages, and the feet of travelling animals, among the surface stones, assist much in binding and fixing them in a firm crust; and in making the road immediately passable by horses and light carriages; most particularly if the whole be compressed, and united together with a heavy roller (suitable to the purpose), repeatedly passed over the surface of it. And another good method of saving expence in this way, where materials are readily procured, is that of placing the coarse unbroken stones or other hard materials in the bottom part or bed of the road, covering them over with gravel, or other sorts of materials that are of a small kind. However, where the hard materials are broken down small and evenly the roads are found to wear the best.

The proper materials for repairing roads are in a great measure the same as those which are used for the making of them in the first instance. The writer of the *Agricultural Report of Middlesex* thinks the rounded stony materials of the nature of flint, found in gravel pits and river bottoms, are in every respect more fit for roads than any other stony matters. The materials for the support of great public roads should, it is supposed, be selected from among such stony substances as are tough as well as hard; for this purpose, hornblende is believed to be particularly suitable, to which may be added whinstone, basalt, iron-ore, and all such stones as contain iron, as well as the slag, or the refuse of furnaces. The comparative weight which stones of similar size and figure can support without being broken, it is imagined, the criterion by which to try them for this use.

Mr. Beaton thinks, that if the above directions were strictly attended to, and every appearance of a breach or defect in a road at once repaired, the same materials, when displaced, would very often, if properly relaid, and fit for the purpose, repair the part beginning to fail; whereas, if neglected for some time, and allowed to get much out of repair, it will probably require a considerable additional quantity of materials, and thereby occasion a great deal of expence that might have been saved. He also suggests, that during the time of hard frost, it may be very proper to drive materials, and lay them down for the purpose of being at hand to repair the roads when the season permits, but such a time is the most improper of any for applying those materials. And that in laying them down it is a very general practice to place them in small heaps along the sides of the road, and even encroaching sometimes very much upon the space allotted for travelling on. This ought on no account to be allowed (unless those materials are to be immediately used), for reasons so obvious, it is unnecessary to mention them. It would be much better to have recesses at certain convenient places, for the purpose of laying the materials in till wanted; by which means the inconveniencies attending the common way would be totally

avoided, and travellers might then, without interruption, use any part of the road they found best; and besides, there would then be less occasion for making the roads so wide as they are generally made, which would undoubtedly save a great deal of money in keeping them in repair, or proper condition.

It is stated, that rolling of roads with a heavy roller, as directed above, would be a very beneficial practice in keeping them in good repair, especially if the hard materials, that are worked out of place by the wheels of carriages, are raked in again previous to the roller passing over them. This would be an easy and expeditious operation, and if taken in proper time, would, in many cases, be all that is necessary to put the road in repair. It is, however, an implement that is very seldom made use of for this purpose by the overlookers of roads.

And the use of machinery has probably been hitherto too little attended to in the execution of this sort of work; but from the increasing price of hand-labour, it certainly at present demands the serious notice of the managers of this sort of business. For dragging over roads, when much out of repair, in order to replace the stones or gravel disturbed by wheel-carriages, a sort of harrow has been invented by Mr. Harriott of Great Stanbridge, in Essex, for which he received a premium from the Society for the Encouragement of Arts, &c. and of which he gives the following account. "Being appointed surveyor of the roads at Michaelmas, 1786, and finding them very bad, I provided a sufficient quantity of stones and gravel against the next summer, to cover the roads pretty thick; but when so done, I found the heavy loads of chalk, gravel, and corn, soon turned the stones out, and made almost as deep a rut or rake as ever. Stubbing the quarters in I found an endless job, as well as a great expence; I, therefore, contrived the road-harrow, and by the help of which I have, during the last summer, at a very trifling expence to the parish (after the ruts were again filled up with stones), kept the roads in extraordinary good condition. A man, a boy, and two horses will do three miles in length in one day, completely harrowing down the quarters, and drawing the stones together, which, by means of the mould-boards, are dropped into the ruts, far better than a man can stub them in. Now, if a man was employed to stub, he could not do it for less than a penny *per* rod, of sixteen feet and a half, (the most common is three halfpence, or two-pence *per* rod, if they stub the outside as well as the inside quarter,) which would amount to one pound six shillings and eight-pence for one mile in length, consequently to four pounds for three miles, which the road-harrow will do in one day; and for which I charge the parish for man, boy, and horses, only eight shillings." And it is further stated by him, that it does the work better, as well as cheaper; that several other parishes are using them, and he thinks the use of them will soon become general, especially where roads are mended with gravel. The head of the harrow is three feet long, from outside to outside of the bars. The bars four inches square, and the length of them five feet. The mould-boards extend eleven inches farther, which is necessary to draw the stones (which the teeth of the harrow work up to the top) nearer the middle of the road. The mould-boards are four feet two inches long, ten inches deep, and two inches thick; they are shod with a bar of iron, and lined about six inches high with an iron plate. The teeth (which should be steeled at the points) are one foot in length, from the under side of the bars to their points; they are one inch and a quarter square, and are fixed with strong nuts and screws, with collars both on the under and upper side of

the bars. The bars are made to go lengthwise instead of across, to prevent them from splitting. The harrow is drawn by two horses abreast, a boy leads the outside horse on the outer quarter, the other horse goes on the horse-path, the man steadying the harrow by the handles. Of course they take one inside, and one outside quarter as they go, and the other two quarters as they come back. And as this harrow is certified, by several people in the parish where it is used, to do more work with one man, a boy, and two horses, in one day, and in a much better manner than could be effected by twenty men in the same time in the usual way, it must certainly produce a prodigious saving both of time and money, and having been found to answer the purpose so extremely well, renders it worthy of attention by those engaged in this kind of work.

Mr. Beatson suggests, that after the use of this harrow, the heavy roller, noticed already, would have a very good effect, or there might be a roller of a lighter construction fastened behind the harrow, to roll at the same time; although the heavy roller would certainly make the best work. And likewise that other implements, nearly on the same principle, have been constructed, particularly one of which he has shewn a model by a gentleman near Chester. Its shape is in form of an isosceles triangle, which is laid upon the road, and drawn by shafts at the base. The two sides, by meeting in an angle opposite the base, are supposed to draw the loose materials towards the middle of the road. It has two small wheels near the base or front, and one at the angle in the rear, with different contrivances for fixing the whole frame higher or lower as required.

It is also suggested that a machine for the more easily breaking stones to repair roads in the common way would be of very great use, as at present this is a tedious and laborious task. Under the article MACHINE, a very ingenious contrivance for removing the mud and dirt from roads has been described. But, although several contrivances have at different times been proposed for facilitating the repair of roads, and lessening the expence, yet that expence, Mr. Beatson says, is no doubt very great, especially in those places where many heavy-loaded carriage continually passing. The ruts made by the wheels soon become so deep, and the materials of the road are thereby so much torn up, that it is almost an impossibility, however hard the materials, to keep the road for any considerable time in proper condition, or state of repair. It is, therefore, suggested, that these effects should be attempted to be remedied by some means or other, as by a sort of roller so fixed as to prevent the wheels from sinking so as to form ruts.

It is evident that the principles and directions which have been given apply equally to private or parochial roads, which in general are in a worse condition, from their being commonly worse managed. The causes of their being in bad condition should be attended to and removed, as much as possible, in the manner already suggested, as it is evident that they must have a great effect in promoting improvements in agriculture, by lessening the expence of labour, and facilitating the means of conveyance of different articles. The effects of some sorts of wheels have been more destructive to roads than others, and of course acts of parliament have been formed with the view of affording proper regulations in this respect. See WHEEL and WAGGON.

In speaking of the draft from friction on the roads, Mr. Middleton, after considering what happens on those made with gravel, and on iron railways, concludes, that, on gravelled roads, friction is not more than one-fifth part of the entire draft; the other four-fifths being occasioned by

the obstacles of dust, sludge, loose sand and gravel. Hence it follows, he thinks, that by removing these obstructing causes, and keeping the roads constantly clean and hard, the draft would be so much lessened, as to render the present number of labouring horses unnecessary. It is suggested, that many of these inconveniences may be got rid of; and the roads be in the way of getting more dry, clean, and hard, by removing the offending matter while in the state of dust, when it occupies the least possible space, and is in the most favourable condition for being taken away. A small portion of dust, it is said, when drenched with rain, becomes a large quantity of sludge, in which state it requires much labour to clear it away; on which account it is very advantageous to get quit of it before rain falls. This is, it is supposed, best effected by means of bush-harrows wrought every windy day. But some might be taken away after being scraped together by suitable machinery for the purpose.

It is intimated, that the time seems to be approaching, when iron must be made to contribute largely towards the public roads. It is thought that iron rails, or bars, may be laid along the present turnpike roads, in such a manner as to afford the most convenient track for all heavily laden carriages; and that this may be done without any material inconvenience to those of lighter weight and swifter speed. The great original expence of making such roads will, it is supposed, be sufficiently counterbalanced by their much longer duration, and the trouble fully compensated by the superior pleasure of travelling over them.

On the whole, it is supposed, that the keeping of roads in the most perfect repair is an object of high importance; for that until canals, or inland navigation, became general, the supply of the markets, and the price of every article, will be in proportion to the state of the roads over which they have to pass in their way to towns. Bad roads, it is said, require a greater number of horses to draw any given weight along them, than would be necessary for the conveyance of the same weight over good ones; which extra draft must be paid for by increasing the price of the article to the consumer. The same number of horses which, along *bad roads*, could only bring a scanty supply of the produce of the country from a small distance, can, on *good roads*, convey a more abundant supply, and from greater distances: which is calculated to lower the price of the necessaries of life in the metropolis and other large towns, rather than advance them in the distant counties, and have a happy tendency towards equalizing the prices between the towns and the country.

And the author of the paper already noticed, thinks it a matter of great consequence to have proper regard to the nature of the fences on the sides of roads, as on these the goodness of them, and the expence of upholding them, very much depend. Where the form of the ground and situation will admit of it, the sunk fence from the road, that is, with the deepest part towards the field, is by far the best. A fence of this sort, in the form of a ditch or drain, may be made of any depth without the least danger or inconvenience, which is not the case when open to the road; and the deeper it is made, the better effect it will have in keeping dry the foundation of the road, if properly constructed; nor will the road require to be so wide as usual, at the same time there will be fully more room to travel on; for if the fences are of this kind, the whole width of the road may with safety be occupied, but when open to the road a considerable space is lost, by the fear or danger of approaching too near them. And the fences on the sides may either be of stone, sod, or a bridge or paling; but ought not to be more than eighteen

inches, or two feet above the level of the road (except a paling), and the top of them, if broad enough, may, in some places, be made to serve as a foot-path. Nevertheless, the fence towards the field may be six feet in height, or as high as the purpose of it requires. The road will thus receive the whole benefit of the sun, which is very essential towards keeping it dry, as well as the depth of the drains or ditches within the field, to which there must be proper openings at certain distances, as before recommended; and in winter, after heavy falls of snow, there will be little chance of a road fenced in this manner ever being blocked up, for it will be observed, when a storm of snow is attended with a high wind, that the drifted snow lodges chiefly about the fences, or where it meets with an obstacle to occasion an *eddy*; for where high fences are on the sides of roads, they are almost to a certainty in such cases blocked up, to the great inconvenience of the whole neighbouring country or district in which it happens. The planting of trees on the sides of roads should always be avoided as much as possible; but where rows of them are to be put in, it should never be done at less than ten or twelve feet distance from the fences, and not less than forty or fifty feet from each other, being constantly so situated as not to produce much shade on the road in the middle of the day.

ROAD, in *Ornamental Gardening*, that sort of carriage-way which is peculiar to residences of the country kind. They are of many different sorts, according to the nature, circumstances, and situations of the different places. But when properly laid out and formed, they have mostly one of the effects of building, at least, in a partial manner, which is that of giving force and spirit to scenes of verdure and cultivation. They should be laid out according to the nature of the situations; their directions and widths being provided by their conveniences, propriety, and utility. The methods of making and repairing of them are much the same as those employed for other kinds of roads; but in the finishing, their surfaces should be laid over with a finer and better coloured material of the gravel or some other sort, and they should be kept more perfectly rolled down and level; as the colours of such surface materials and the margins of such roads are principally what concerns picturesque effect, or that which is to be produced by them. In situations where the scene is avowedly of the artificial kind, the margins of them, according to the author of the work on "Country Residences," should be parallel to each other, and correctly defined; as in that part of an approach-road, which comes within the parapet or fence which incloses the mansion, or in those roads which are within the bounds of the other more adorned parts of the ground. But in situations where the roads are not in these scenes, but are either in picturesque or natural pleasure-grounds, pasture-fields, parks, forests, dingles, or other similar places, the edges should be irregular, and more or less rough or smooth, blending or ragged, as is seen to take place in roads or tracks through similar scenery in wild nature. The excellent effects and superior advantages which result from the adoption of these principles in the formation and construction of roads of this nature, may often, it is said, be seen in those parts of much frequented approach-roads of residences, which are not thought proper or necessary to be subjected to the operation of the paring-iron, and the formal trimming of the gardener. And indeed, that one of the most striking deformities in picturesque scenery, is that of the formal, stiff, and harsh edges of made roads, as they highly disgust the spectator, and prevent the true effect which should be produced.

All roads of this sort should, therefore, be laid out, and

formed in such a manner as to harmonise as perfectly as possible with the nature, circumstances, situations, and scenery of the particular places in which they are to be had recourse to. See *WALK*.

ROAD, Approach, that variety of this sort of road which is peculiar to residences, mansions, or houses of the country kind, and which leads or conducts to their principal or other entrances. In their manner of being laid out, they should in their directions neither be too affectedly graceful, have too much waving in their appearance, be too much beset and intercepted with trees; or be too vulgarly formed in the rectilinear and direct manner, or be too abrupt in their nature. There is a certain kind of dignity, propriety, and fitness requisite in them, which is not easily described, but which, in given situations and circumstances, readily presents itself to the mind of the designer; and in consequence of the whole of the operations, both of conceiving and designing them, being so simple, they are, for the most part, marked out upon the ground with great facility,—easily improved upon, and, in their execution, the work is merely that of road-making.

The accompanying circumstances which appertain to roads of this nature have been already pointed out in speaking of them in general, and they ought to be well attended to, as much of their beauty and effect arise from them.

The only proper approach-roads to castles, Mr. Loudon says, have been supposed those of the avenue kind, but that there seems no reason in nature for such a rule; and the arguments drawn from antiquity are wholly insufficient to justify their constant introduction in such cases. However, wherever they exist with good effect, they should, it is said, be carefully preserved; and even, in some situations, avenue roads to mansions, straight private roads through monotonous cultivated countries, or public roads passing along eminences, may be created and formed with great advantage and effect, as is the case in many places. Roads of this kind should always be so contrived as to afford the best effect, and to produce the greatest harmony, which the places are capable of admitting.

ROAD, Drive, another description of road belonging to residences of the rural sort, which is chiefly designed to shew and display the beauties of the places, or of the surrounding country, or of both at the same time. They are principally had recourse to in residences of the more extensive and elegant kind, being mostly contrived without any great difficulty. The main circumstance to be attended to in this business, is that of only shewing one sort of rural character at one time, but to display the whole, in succession, as much as possible. They are commonly formed, as to the road part, without much labour or trouble, being often simply made by levelling, and the materials upon the spot; they may, however, be constructed in the same manner as the other roads in such situations.

The leading, or striking characters of the spot, are here to be particularly regarded.

ROAD-Gage, a contrivance for the purpose of breaking road stones, or other hard materials, by. A ring, or an oval, of iron, of the proper size for the intended use, with a short handle fixed to it, will answer this intention very well. These gages are of great use in breaking stones by the load, or in other ways, before they are laid upon roads; and should always be known to the workmen previous to their undertaking the business. See *ROAD Stones*.

ROAD-Harrow, an implement of the harrow kind, contrived for the purpose of forcing in the sides of the ruts. One represented in the Essex Agricultural Survey levels the

ruts and combs very expeditiously. It was invented by Mr. Patten, and costs 5*l*. See *ROADS*.

ROAD-Horse, such a one as is employed in the teams on the road, and which in general performs the most laborious work. Under this description comes the greater part of all the horses in constant use, as it includes carriage horses of every kind, roadsters, and hacks. Road-horses of every denomination are, from their constant hard work, entitled to a proportionable degree of care and attention with the best horses in the kingdom; and should undergo the useful part of stable management, that so much contributes to the preservation of health in horses of a superior description. Those which have incessant labour, or which travel post, must be supplied with at least from one to two pecks of corn a day. Large and strong carriage horses, in perpetual work, require considerably more, or they will become apt to lose flesh by frequent perspiration. These rules, however, offer only a kind of general standard.

ROAD-Materials, all such substances as are employed, or made use of, in the making and repairing of roads; as those of stony matters of different kinds and qualities, various sorts of gravel, sand, and a variety of other articles. They should, in every case, be reduced as much as possible to the same sizes, as the regular wear of roads depends very much upon it. See *ROAD*.

ROAD-Pick, an useful implement of this kind with three points. It has much resemblance to the common pick-axe, only differing from it in having the flat edge-like end of that tool occupied by three strong tines, about six inches in length, and standing about six inches in width from the outside to the outside of them. It thus forms a sort of small trident, which is borne on the shank of the implement, and stands about six or eight inches from the socket and handle.

It is a very convenient tool in striking off the protuberances, and filling in the ruts of hard roads; as well as to level and adjust the surface with, in forming and repairing stone roads. The single end is likewise capable of being employed for letting off water from shallow ruts, or hollow places, as well as for many other uses of the common pick. See *PICK*.

ROAD-Plough, an instrument of the plough kind, invented and made by the late Mr. Brand, an ingenious blacksmith, in the county of Essex, at Lawford, near Manningtree. It is formed all of iron, and represented in the Agricultural Survey of that district. Its length is that of a common plough, with two small wheels, one before and the other behind; and the coulter part is strongly secured.

ROAD-Roller, a heavy kind of iron roller, formed in three separate parts, used for rolling down the loose materials on roads. It is drawn by a horse or horses in shifts, somewhat as in the common roller. See *ROADS*.

ROAD Scraping Machine, a contrivance made for the purpose of cleaning roads from dirt, &c. These machines are constructed in several different ways, by different makers; but a very useful one may be seen under the head *Machine*; which see. See also *ROAD*.

ROAD-Stones, all kinds of stones, whether of the field, quarry, or other sorts, that are employed in the forming and mending of roads. For some uses of this nature, the stones should be considerably reduced, even in constructing or repairing ordinary roads. Mr. Marshall has suggested, that by dropping road-stones through circular gages of different sizes, it will be found that, for repairing small breaches, those which pass freely through a ring, 2½ inches in diameter, may be considered as of a middle size; and

that for new forming or fresh covering the surface of a road, none are to exceed 4 inches; $3\frac{1}{2}$ inches being, for these purposes, the middle size: that 2 inches and 4 inches may, as a matter of general information, be set down as the extremes of size of road-stones of a middle quality, for the above purposes. See *ROAD-GAGE*.

ROAD-Surveyor, a person who has the care and management of a road, whether in the making or repairing of it. All such persons as are employed in this way should be well acquainted with the nature of laying out, forming, and keeping them in order. Each of the different methods, which are in common practice, ought to be well understood, as well as those had recourse to in particular districts or places. And, besides, he should be well informed with regard to every thing of a local nature that has any relation to them, and be a man of exertion and ingenuity.

ROAD-Team, any sort of team that is employed on the road, whether in carts, waggons, or other kinds of carriages. All teams of this nature should in general be well kept. See *TEAM*.

ROAD-Work, all such kind of work as is done upon the road, either by the labour of men or animals. It is also sometimes applied to the business of making and repairing of roads.

ROAD, in *Navigation*, denotes a place of anchorage at some distance from shore, and sheltered from the winds, where vessels usually moor to wait for a wind or tide proper to carry them into harbour, or to set sail.

When the bottom is clear of rocks, and the hold firm, and the place well covered from the wind, the road is said to be good. An open road is one which has but little land on any side.

The roads within his majesty's dominions are free to all merchant vessels, either of his subjects or allies. Captains and masters of ships who are forced by storms, &c. to cut their cables, and leave their anchors in the roads, are obliged to fix up marks or buoys, on pain of forfeiture of their anchors, &c.

The masters of ships, coming to moor in a road, must cast anchor at such a distance as that the cables, &c. may not mix, on pain of answering the damages. When there are several vessels in the same road, the outermost to the seaward is obliged to keep a light in his lantern in the night-time, to apprise vessels coming in from sea. See *PORT*.

ROAD Aqueduct, is an arch under a canal, through which a road passes.

ROAD Bridge, a bridge over a canal for the use of a road, instead of private use. See *OCCUPATION Bridges*.

Roasting

ROASTING, in *Metallurgy* and *Chemical Manufacture*, is a process by which the volatile parts of metals and minerals are separated by the application of heat. The minerals are generally mixed with the fuel, and fired in heaps exposed to the open air. When the volatile substance is driven off with difficulty, the reverberatory furnace is sometimes employed.

This process is frequently, though improperly, called *calcining*, since the latter is confined to the oxydation of metals. In expelling the volatile parts from lime-stone and gypsum, the process is termed *burning*, and in the latter sometimes *boiling*. The term roasting is principally confined to iron, and other ores abounding with sulphur and arsenic.

The iron ores of this country are roasted for the purpose of expelling sulphur, water, and carbonic acid. The former would probably injure the quality of the iron in smelting;

the latter would contribute to an expenditure of the heat of the furnace. The process is conducted in the open air, by piling the iron-stone and small coal in alternate strata, allowing the mass to burn till the coal is consumed. The iron-stone, by this means, becomes of a red colour, and loses much of its weight. In some iron-works the process is performed in kilns, similar to those employed for burning lime-stone.

The ore from which zinc is obtained is generally blende, which is the sulphuret of that metal. It is exposed to the strong heat of a reverberatory furnace, by which the sulphur is expelled, and the metal oxydated.

When the metals or their oxyds are themselves volatile, and are combined with sulphur, roasting is not practicable: recourse must then be had to some other agent, which will combine with the sulphur, and separate the metal itself. Such is the case with *cinnabar* and *arsenic*. See the respective metals.

Rock-salt

ROCK-SALT, in *Mineralogy* and *Geology*, a natural salt, of the same kind as common table salt. This useful mineral forms large beds and masses in many parts of the world, and even composes entire mountains. It occurs in large columnar or in spheroidal concretions, and also crystallized in cubes. Rock-salt is subdivided by Werner into two kinds, foliated and fibrous. The more common colours of foliated rock-salt are, white, grey, reddish-brown, and red; but sometimes it is violet, sky-blue, and green, and is more or less transparent or pellucid: it breaks into cubical fragments, which have a vitreous lustre: the structure is indistinctly foliated. In fibrous rock-salt the fibres are generally small and curved; in other respects it differs little from the former. The taste of both is like that of common salt. The red varieties are coloured by earthy matter and oxyd of iron; the white and transparent are extremely pure, being composed almost entirely of muriatic acid and soda, or, according to Davy, of chlorine and sodium. In the purest kind also, there is scarcely any trace of water of crystallization.

According to Henry, pure transparent rock-salt, calcined for half an hour in a low red heat, equal to four or five degrees of Wedgwood's pyrometer, lost absolutely nothing of its weight. It is remarkable, also, that if free from any adventitious moisture, it may be suddenly and strongly heated with scarcely any of that sound called decrepitation, which is produced by a similar treatment of all the varieties of manufactured common salt. The specific gravity of the purest specimens of rock-salt is about 2.170, of the less pure about 2.130.

Rock-salt is widely distributed over the globe; it appears principally in the lower secondary strata. It is most frequently accompanied with sulphate of lime or gypsum, and by beds of clay impregnated with salt. Beside the beds of rock-salt which are known, numerous brine-springs in various parts of the world attest the existence of this mineral deep under the surface, as it is evident these springs percolate beds of salt, or strata impregnated with it. Several brine-springs have recently been discovered in the deep coal-mines

of Northumberland and Durham. In the coal-mines near Ashby-de-la-Zouch, in Leicestershire, there are springs of brine 245 yards below the surface; and though these springs are in the centre of the island, they are 140 yards below the level of the sea. How much deeper their source may be, has not been ascertained.

The most obvious hypothesis respecting the formation of rock-salt is, the one which supposes that it was deposited from the sea, or by the deliquescence of salt lakes which formerly covered the present continents. Against this it has been objected, that the composition of rock-salt is much more pure than the contents of sea-water, which contains a quantity both of muriate and sulphate of magnesia, sulphate of soda, and of sulphate of lime. Rock-salt is also found at great heights above the present level of the sea. These objections will, in a considerable degree, be invalidated by the consideration that whatever impurities there may be in sea-water, if the process of evaporation go on very slowly the salt will be crystallized nearly pure. Of this we have an instance in the species of salt made at Lymington, in Hampshire, called *salt cat*, which is gradually formed in the course of ten or twelve days, by spontaneous evaporation of the liquor which drains from the common salt. This salt is so pure (though evaporated from the most impure part, the mother water, or residue of sea-water), that 1000 parts contain only 12 of foreign impurities, or little more than one *per cent*. Thus if the deliquescence of lakes or basins filled with salt water were very gradual, as it must be, except in the vicinity of subterranean fires, the muriate of soda or rock-salt would be crystallized before the other salts, which being more deliquescent might be separated and washed away. In this manner the sulphate of lime or gypsum, which exists in sea-water, and accompanies rock-salt, may also have been deposited, and being nearly insoluble would remain.

The occurrence of rock-salt deep under the earth, or high above the level of the sea, can scarcely form an objection to its formation from sea-water; for it is admitted by all geologists, and is proved by undoubted facts, that the ocean once covered our present continents. Now by whatever process the dry land was raised above the sea, whether by the elevation of the former, or the depression of the beds of the latter, extensive hollows and closed vallies must have formed lakes of salt water, from which the salt might be deposited by evaporation. Some of these vallies or hollows would occur in elevated situations. With respect to the beds of rock-salt placed under other strata, however difficult it may be to explain the formation of the secondary strata, the existence of organic remains in them prove that each stratum was once the uppermost part of the globe, and the strata by which it is covered were deposited upon it in successive and probably at distant periods. Nor is the difficulty greater with respect to the strata covering rock-salt, than the strata covering coal and beds of coal-shale abounding in vegetable impressions. No organic remains have indeed been discovered in the strata over the rock-salt of Cheshire, but they are commonly met with at greater depths over the rock-salt beds in Poland, and in other parts of Europe. The occurrence of rock-salt at the sides or feet of extensive mountainous chains, may perhaps illustrate its formation, as it is probable these extensive chains once formed the boundaries of inland seas or lakes, when the relative level of the ocean and our continents was very different from the present.

Rock-salt is not mined in any part of our island, except Cheshire, though it was bored through at Droitwich; and it exists, in all probability, in many of the

western counties through which the red sand-rock extends. We have proofs of its existence from the brine-springs at Droitwich, in Worcestershire, at Lemington in Warwickshire, and at Ashby Wolds, in Leicestershire; and also in the counties of Northumberland and Durham, on the eastern side of England. The springs at Droitwich furnish a brine as strong as those of Cheshire. A description of the rock-salt of Cheshire being given as an article of rural economy, we shall proceed to give a short account of the most important repositories of this useful mineral in other parts of the world.

Salt is very abundant in Africa; all the plains and sandy deserts are impregnated with salt, and the greater part of the springs in these deserts are so saline, that it is not possible to drink the water. To the south of Abyssinia, at the feet of the mountains which separate that country from that of the Gallas negroes, salt exists in dry and solid masses. The summit of the mountains which border the desert to the west of Cairo, presents an immense plain covered with a mass of salt. According to Horneman it is spread over so large a tract of surface, that no eye can reach its termination in one direction; its breadth extends several miles. To the west of the desert of Sahara are the great salt rocks of Tegaza, on the south-east frontier of the desert of Zuenziga, a little distance from Cape Blanc. They are worked by the Moors. These salt mines furnish the white and coloured salt, which is carried by caravans to Casnah and Tombuctoo, to supply the Negro states; for it does not appear that there are any salt mines in Negro land properly called. The mines of salt spread in that part of Africa which the ancients called Libya, have been well indicated by Herodotus, and it is in this country that he has described buildings constructed of rock-salt, like those in Caramania and Arabia. Other salt mines, according to Park, are found on the southern frontier of the great desert Sahara. Their produce is also sold to the Negroes on the borders of the Niger and the Jolibe. In the kingdom of Tunis, mount Had Delfa is entirely composed of very compact salt of a red and violet colour. The lake des Marques, and the plains near it, also contain much salt. There are mines of rock-salt in the country of Bamba, in the kingdom of Congo. On all the western coast of Africa there are salt lakes and marshes. In the neighbourhood of the Cape of Good Hope, and in Caffraria, rock-salt is less common; but there are salt lakes to the east of the Cape, on the frontiers of Caffraria, which contain at the bottom beds of salt variously coloured.

Salt lakes exist in the Cape Verde islands, and natural salt-marshes, particularly in Bona Vista.

Spain is the only country in the south of Europe which contains extensive repositories of rock-salt in considerable masses above the surface. It is found there in elevated situations, forming entire hills: brine-springs also issue from the feet of the mountains which traverse that country. According to the description of Mr. Bowles, the repository of rock-salt which lies between Caparoso and the river Ebro, is in a chain of hills which extend from east to west. These hills are composed of lime-stone, mingled with gypsum, the chain extending more than two leagues. In the most elevated part is situated the village of Valtierra, on a slope towards the middle of which is found a bed of rock-salt. It may be about 400 paces long, and 80 wide. The salt is contained in a bed of about five feet in thickness.

"I examined," he adds, "with attention those beds of salt; I compared them with the layers of earth and gypsum in which it is imbedded; I found the outside layer to be composed of gypsum; and, immediately afterwards, I met with

two inches of white salt, succeeded by two inches of stony salt, and a layer of earth. I found others alternately composed of earth and salt to the very bottom of the mine, which is of gypsum, undulated like the other layers. The layers of saline rock are of a dusky blue, those of salt are white.

"This mine is considerably elevated above the sea, for you ascend continually all the way from Bayonne.

"The second hill is that of Cardona, in Catalonia, near the mountain of Montserrat, sixteen leagues to the N.W. of Barcelona, and a few leagues from the Pyrenees.

"The village of Cardona is situated at the foot of a rock of salt, which, from the sides of the river Cardener, seems nearly mural. This rock is a block of massive salt, which rises from the earth about four or five hundred feet, without crevices, chasms, or layers. No gypsum is found near it. This block is about a league in circumference; and its elevation is equal to that of the surrounding mountains: as its depth is not known, it is impossible to say on what it rests.

"In general, the salt, from the top to the bottom, is white, though some parts are red; some is also found of a fine blue. There are also in Spain other repositories of rock-salt and saline springs. In La Mancha, at Almengranilla, there is a mass of salt similar to that of Cardona; it is seventy yards in diameter, mixed with sulphate of lime, and covered with the same stone, including crystals of red quartz; above which are siliceous pudding-stones, and a stratum of carbonate of lime."

The mines of rock-salt that are wrought at Pozza, near Burgos, in Castille, are remarkably situated, being placed in a vast crater. A French traveller, M. Fernandez, found pumice-stones, puzzolana, and other volcanic productions there.

Rock-salt is likewise found near Aranjuez and Ocanna, in the transition hills between Sierra Morena and Madrid.

On the north side of the Pyrenees no beds of rock-salt have been discovered, but numerous brine-springs occur, particularly at Salies: in the department of the Lower Pyrenees the soil is calcareous, and sulphate of lime is found in the neighbourhood of the spring.

There are salt-springs at Salies, to the south of Thoulouse, also at Salins and Montmorat, in the department of the Jura; in the first of these the water contains fifteen *per cent.* of salt.

There are about twenty brine-springs in the department of La Meurthe, which contain, on the average, thirteen *per cent.* of salt. These springs are at no great distance from each other; some are at the foot of the chain of Jura, the others at the foot of the Vosges: the product of these brine-springs supplies Switzerland with salt. There are salt-springs in the department of Mont Blanc, in the midst of the Higher Alps. In the same department, near St. Maurice, there is a salt-rock near the region of perpetual snow, which is probably the highest situation in Europe where this mineral occurs. The rock consists of gypsum, intermixed or impregnated with salt, which is extracted by solution in water; the insoluble part remains porous and light. Various brine-springs also occur in other parts of France.

Though there are numerous brine-springs in the north of Germany, no beds of rock-salt appear on the surface, until we approach the circle of Austria and the neighbouring countries. The range of salt-rocks commences at Halle, in the Tyrol, passes through Reichenenthal in Bavaria, and continues to Hallein in Salzburgh, Hallstadt, Ischel, and Ebenfel, in Austria, and terminates at Ausse in Styria.

The salt at Ausse is worked in a peculiar manner: parallel galleries are run into the rock, in these dykes are formed, and water is let into them, where it remains from five to twelve months. When the water is saturated, it is drawn off in pipes, and the solution is evaporated.

On comparing the geological situation of the greater part of the beds of rock-salt and brine-springs, it will be seen that they occur most frequently at the foot of high mountainous chains. The mines of rock-salt in Transylvania, Upper Hungary, Moldavia, and Poland, may be cited in further proof of this. These mines are numerous, and very important from their extent, and the vast masses of salt they contain. They are found along the chain of the Carpathian mountains, and spread nearly in an equal degree on each side of the chain, accompanying these mountains to the extent of more than two hundred leagues, from Wieliczka in Poland, towards the north, to Fokizian or Rymnick in Moldavia, to the south.

The strip of land that contains the salt-rock or brine-springs, is near forty leagues broad in some parts. In it may be reckoned about sixteen mines, that are worked for salt; forty-three indications of mines that have never been wrought; and four hundred and twenty, or four hundred and thirty, brine-springs.

The most remarkable of these commence in the north-east, and extend in a southerly direction, including those of Wieliczka, Bochnia, and Samber, in Poland; and some brine-springs in Buchovina and Moldavia, particularly near Ockna. On the south-west of the chain, following the same direction, are those of Sower, near Eperies, in Upper Hungary; of Marmarosch, in Hungary; of Dees, Torda, Paraid, and Visackna, near Hermanstadt, in Transylvania, &c.

The salt-mines of Wieliczka, near Cracow, and those of Bochnia, which appear to be a branch of them, have become celebrated from the accounts given of them by almost every traveller who has visited that country; many of their descriptions are too highly coloured. They are, indeed, very ancient, having been worked ever since the year 1251; but have nothing to distinguish them above others, except the extent of the works in the beds of rock-salt, the dimensions of which still remain unknown. The ground that covers the rock-salt is composed, like that over most other salt-mines, of alternate strata of sand, pebbles, and marl, including large blocks of salt. You go down to these mines by six shafts, of four or five yards in diameter. Various structures have been formed in the body of the salt itself. We find there a stable, chambers, and chapels, all the parts of which, as pillars, altars, and statues, are of salt. The shafts and galleries are perfectly dry, so that you are more incommoded by dust than dirt. There are springs, however, both of salt water and of fresh in these mines. It appears that the air is not so foul in them as in most salt mines; but the workmen do not reside in them, as some have asserted. In certain parts of the mine, hydrogen gas sometimes collects and explodes.

The salt is cut out in little ascending steps. It is formed into parallelepipeds, weighing about eighty or a hundred pounds, or into cylinders, which are put into casks. This mine produces about six thousand tons of salt every year.

According to the description of Dr. Townson, the salt in the upper mines does not form continuous strata, or rocks, but exists in immense detached blocks or masses, imbedded in marl. He gives the following account of the strata which cover the salt.

Vegetable soil	-	-	-	-	-	4
Sandy clay	-	-	-	-	-	10
Fine sand effervescing with acids	-	-	-	-	-	7
Marle with sand, containing fragments of sand-stone	-	-	-	-	-	18
Sand-stone	-	-	-	-	-	2
Marle mixed with salt, in small particles and cubes	-	-	-	-	-	40

At the depth of forty yards in this marle the salt is found. The blocks of this mineral are of such a size, that in passing through the galleries formed in them, sometimes the upper, and sometimes the lower end only of a block may be seen; but often, though the galleries are three or four yards high, the breadth can only be observed, and even in some places the blocks of salt form the sides of the gallery for fifteen or twenty yards. These blocks compose the upper bed of salt, and from them the whole of what is called the green salt is obtained. This salt, which is of a greenish or blackish hue, owes its colour to numerous fine particles of a substance which seems to be of the nature of argillaceous schistus scattered through it. This variety of salt, on account of its impurity, is retained in the country for home consumption. In this marle, also, blocks of sand-stone are sometimes found imbedded, and the marle itself is strongly impregnated with salt. Lower down there is another bed of salt, called *szybicker salt*, which is in some places two or three yards thick; it is of a purer quality than the former, and is exported to foreign countries. This variety of salt-rock is disposed in very extensive beds. The mine has been driven in one place twelve hundred yards, from east to west, and four hundred from north to south; salt being still found there. The utmost extent is yet unknown. The nature of the stratum beneath the *szybicker salt* has not been ascertained; for the miners, being apprehensive of increasing the quantity of water, have never proceeded to a great depth in this stratum. The greatest depth of the mine is two hundred and forty yards. It does not appear that the remains of organized bodies have been found in great abundance in the strata connected with the salt-rocks now described. None have been observed, according to Dr. Townson's information, in the *szybicker salt*, or the lower strata; but some have been seen in the marle which envelopes the block of green salt; such as bivalve shells, at the depth of seventy-two yards; crabs' claws, at the depth of eighty yards; and charred coal, mixed with salt and gypsum, at the great depth of two hundred yards.

From the circumstance of mas being formerly celebrated in these mines two or three times a week, it has been said that the workmen, to the amount of five hundred, live constantly below ground. They do not, however, continue longer than their hours of working. To keep the mines dry, the salt water is drawn up in leathern sacks, and is thrown away; the small quantity of fresh water which they afford is reserved for the use of the horses which are employed in the subterraneous operations. At the time Mr. Townson visited them, twenty-four horses were constantly kept below ground.

In the mine of Bochnia the salt presents itself in a stratum at once, and not in detached pieces. The strata of clay, as well as those of salt, are undulated, and not of an uniform thickness. The salt is sometimes brown, at others reddish, and at others transparent. The different coloured salt is not arranged in parallel layers. The strata dip at an angle of about forty degrees with the horizon. Dr. Townson informs us that very beautiful specimens of fibrous muriate of soda are found in it.

At Thorda the mass of salt is divided into horizontal

but undulated strata. These strata are about eight or ten inches thick. The lowest are the most undulated.

Near Ockna, in Moldavia, there is a hill of rock-salt, in many parts of which the salt appears exposed to view.

The mines on the south-east of the Carpathian chain appear more numerous, and are dispersed through a greater space of ground than those on the north-east. They are in general very near the surface. Some of those in Transylvania are so to such a degree, that persons are appointed to cover the salt with turf, when it is washed bare by the rain. These masses, however, are so thick, that their bottom has never been found. They are not worked to the depth of more than a hundred and seventy or eighty yards, because the extraction of the salt becomes then too expensive. In the county of Marmarosch they have been wrought to the depth of upward of two hundred yards. These mines contain likewise a great deal of petroleum, and the ground in which they are contained is every where furrowed by rivers. The mud interposed between the water of these and the salt, is imagined to prevent the salt from being dissolved by them.

At Paraid, in Transylvania, there is a valley, the bottom and sides of which are of pure salt. Walls of salt appear there sixty or seventy yards high.

The mine of Eperies is three hundred and sixty yards deep.

In the salt mines of Marmarosch, water has been found included in the substance of the salt-rock.

The mines of the south-west of the Carpathian mountains are generally wrought by means of shafts. There are at least two to each mine; one for the workmen, the other for drawing up the salt. The salt is cut out in ascending steps, which produces empty spaces, of a conical form, in the midst of the strata. The ladders reach perpendicularly to the bottom of this conical space: so that within it they stand perfectly detached. Thus the greater part of the body of salt is extracted, leaving empty spaces, which are conical, and which communicate with one another by means of galleries. It has been thought, that, in order to leave less salt, it would be better to give these spaces the shape of a parabola. The salt is so plentiful, that the miners are paid only for such pieces as weigh upwards of eighty pounds, the others being rejected as useless. When the workmen are incommoded by water, it is drawn up in leathern bags, to be emptied out of the mine.

The Transylvanians and Moldavians extract salt from their brine-springs, by throwing the water on wood fires, as the Gauls and Germans did in former times.

No salt-mine, or brine-spring, is known either in Sweden, or in Norway.

There are a great number of both, and particularly of salt lakes, in Russia. Among these is the salt lake of Tor, towards the northern extremity of Little Tartary.

There are similar salt lakes in the Crimea.

At Balachna, on the banks of the Wolga, are some very rich brine-springs.

In Russia, in Asia, we find the brine-springs of Permian, of which there are a great number at the foot of the mountains of Poyas.

About eighty versts from Yena Tayeoska, in the desert between the Wolga and the Uralian mountains, there is a mine of rock-salt.

In the government of Astracan, to the north of the Caspian sea, in the environs of Orenburgh, and in the country of the Bashkirians, salt lakes are very common, and the water evaporating during the summer, the salt

appears crystallized on their surface, and round their borders. When this water is highly concentrated, it has a deep red colour. The salt formed in them has often the same hue; and when this is the case, it diffuses a very perceptible violet smell.

One of these is the salt lake of Elton, above Astracan, in the re-entering angle formed by the Wolga. The Kal-mucks called it the Golden lake, because of its red appearance, when the sun shines on it.

The lake of Bogdo, situate near this, yields a perfectly white salt, free from sulphate of magnesia, and preferred to that of lake Elton.

Near Astracan, too, is the mine of Iletzki, celebrated for the quantity of salt it furnishes. The salt lies at no great depth, and rests on a very hard clay. The soil above it is sandy, and full of holes, containing water saturated with salt.

In Siberia there is a mine of rock-salt on the right bank of the Kaptendoi; and on that of the Kawda are fourteen brine-springs. Others are found in the government of Koolivan, and in the environs of Irkutsk, near the lake Baikal, in the centre of Asiatic Russia. Lastly, the country near the Caspian sea is so impregnated with muriate of soda, that in the environs of Gourief, the fogs and dew that settle on people's clothes, and on plants, are saline. Pallas.

Among the Mongul Tartars, the soil is so thoroughly penetrated with muriate of soda, that the people lixiviate it, and evaporate the solution to obtain salt.

That part of China, which borders on Tartary, contains salt-mines, and the ground is strongly impregnated with salt.

Salt is found in the same manner throughout almost the whole table-land of Great Tartary, Thibet, Hindoostan, and particularly Persia, where very extensive plains are seen covered with a saline efflorescence. The isle of Ormus, at the mouth of the Persian gulf, appears, according to the accounts of travellers, to be one large rock of salt. This substance is also found in solid masses near Balach, on the eastern side of Persia. In the desert of Caramania, according to Chardin, rock-salt is so abundant, and the atmosphere so dry, that the inhabitants use it for building their houses. It is found in the neighbourhood of Ispahan, and in the mountains to the north of that city.

The repositories of rock-salt in America are less known. According to Ulloa and others, it is found in vast quantities in the elevated deserts of Peru, at the extraordinary height of 10,000 feet, or more, above the present level of the sea. It is extremely hard, forming solid continuous rocks of a dull violet colour.

The mountain of Xaragua, in the island of St. Domingo, affords salt; and in the same island there is a very remarkable salt lake, about 22 leagues in circumference, called Henriquette. The water, which is inhabited by lizards, alligators, and land-tortoises, all of a large size, is deep, clear, bitter, salt, and of a disagreeable smell. Near the middle of the lake is an island, about six miles long and three broad, well stocked with goats, whence it has the name of Cabrito island; and in this island is a spring of fresh water.

Salt lakes occur in other of the West India islands. In North America, west of the Alleghany mountains, in the state of Kentucky, are numerous repositories of rock-salt and brine-springs: these are called *licks*, where the elks and buffaloes formerly repaired in herds, to lick the soil impregnated with rock-salt. On the western side of the great river Missouri, a chain of mountains extends 80 miles in length, and 45 in breadth, and of considerable height: it consists of pure rock-salt, barely covered with earth, but

without any tree or shrub. Further west, in California, salt is found in a very pure state, in large and solid masses.

From the preceding account it will be seen that this most useful mineral is found in every quarter of the globe; and in many parts it exists in masses of immense size and extent, compared with the rock-salt in our own island, in the county of Chester. Such, however, is the superior industry of our inhabitants, that the quantity annually exported from that county alone greatly exceeds that procured from any other district in the known world, being not less than 140,000 tons, the produce of the salt-rock and brine-spring; while the celebrated mines at Wieliczka, in Poland, are stated to yield only about 6000 or 7000 tons. Where rock-salt is white or colourless, it is immediately applicable to all useful purposes; but when mixed with earthy matter, it is rendered pure by the simple process of solution in water. The liquor is afterwards drawn off into pans, leaving the insoluble part behind; and the water is then evaporated either by the natural warmth of the climate, or by fires. See SALT.

Rock-Salt, in *Rural Economy*, that sort of fossil, rocky, saline material, which is dug out of the bowels of the earth, from different depths, in some parts of this and other countries, where it exists in layers of different thicknesses. The beds of this kind of salt, which are found in the county of Chester, are highly interesting and important to the country, whether considered as affording an article of manufacture and commerce, or as forming a source of revenue. The discovery of the beds or strata of this sort of matter, in this district, is, however, of no very remote date, as will be seen under the head of *Rock-Salt Pits*; but the layers are pretty numerous, and of considerable extent, differing greatly in their purity, though, in many instances, requiring a greater or less degree of preparation before the salt can be used.

It is remarked by the writer of the account of the Agriculture of Cheshire, that, from some experiments made on different specimens of rock-salt, it would appear that the transparent kind of it is an almost pure muriate of soda, which contains no admixture of either earth or earthy salts; and that the colour of the less transparent and brown specimens is derived from the earth that enters, in greater or less proportions, into their compositions. That on 480 grains of transparent rock-salt being dissolved in four ounces of distilled water, there was, first, no precipitate let fall, on the addition of carbonate of potash. Secondly, no alteration was produced by this solution on blue vegetable juices. Thirdly, on the addition of a few drops of tincture of galls, a slight purple tinge was given to the solution; and after standing some hours, there was a brown sediment at the bottom of the vessel. Fourthly, on the addition of muriate of barytes, there was no precipitate thrown down. From the result of these trials, it is supposed that rock-salt has no muriate of lime, or muriate of magnesia, combined with it; from the second, that it has no uncombined acid or alkali; from the third, that it contains some portion of iron; and from the fourth, or last, that there is no sulphate of lime contained in it.

And that, on examining different specimens of the less transparent, and the brown rock-salt, with the same reagents as in the above trials, it was found that these consisted of muriate of soda, or sea-salt, in combination with a certain proportion of earth, varying in quantity from one to thirty *per cent.*; also, that the earth was wholly the argillaceous or common clay; but that some of the specimens contained a few grains of sulphate of lime, in 480 of those of the rock-salt.

The beds of this salt are now well known to be the prin-

cial cause of the salt-brine springs in this county; and, in connection with some other circumstances, to have a great share in causing the vast differences in their strength, in different places. See *SALT-Brine Springs*.

This is a strong sort of salt, which is found useful for a variety of domestic purposes, according to the different manner in which it is prepared, or the difference in the size of the particles or crystals of which it is composed, as will be more fully shewn under the head *SALT*.

Although rock-salt is found in various parts of the above district, there are no pits of it wrought at present, except in the vicinity of Northwich. And part of the inferior rock-salt, which is procured there, is, it is said, used at some of the refineries in that neighbourhood; and a further quantity sent down the river Weaver, for the supply of the refineries at Frodsham, in the same county, and those on the banks of the Mersey, in Lancashire. The purer rock-salt, or that which is called in general Prussian rock, is carried by the same conveyance to the port of Liverpool; whence, according to the above writer, it is exported chiefly to Ireland, and the ports of the Baltic. The annual quantity of rock-salt sent down the first of the above rivers is found, on the average of the last ten years, to be 51,109 tons. But in this, it is observed, is included what is used at the Frodsham and Lancashire refineries, which may probably be about one-third of the whole. And it is added, that it appears, from the report of the committee of the house of commons, appointed to inquire into the laws respecting the salt duties, printed in June 1801, that,

in 1798	} were exported	{ 20,162 33,913 34,939 }	} tons of rock-salt.
1799			
1800			

Of this quantity,

in 1798,	16,095	} tons
1799,	22,374	
1800,	19,663	

were sent to different ports in Ireland: the remainder was principally exported to Denmark, Russia, Sweden, Prussia, and Germany. However, a small quantity went to Guernsey, Jersey, and the West Indies.

This shews, in a striking manner, the great utility and advantage of this article in a manufacturing and trading point of view, as well as in other ways.

In regard to the original formation of the beds or strata of rock-salt, in this and other countries, different theories, opinions, and conjectures, have been formed and proposed; but it is one of those geological questions which is extremely embarrassing in its nature, and very difficult in its solution. Mr. Holland has, however, in the above work, ingeniously stated several suppositions on the subject, and the objections to which they are exposed. It is remarked, that wherever rock-salt is met with, sulphate of lime seems to be very generally discovered in mixture with the earthy strata above it. And the writer of the "*Memoire sur le Ser Marin*," in the 11th volume of the *Annals of Chemistry*, it is added, informs us, that this is the case in Poland, Transylvania, and Hungary; also, that there is commonly a layer of gypsum betwixt the strata of stone and the bed of salt. This gypseous layer is of different colours, and is found crystallized, striated, and mixed with marine shells. The gypsum above the beds of rock-salt in Cheshire is, in like manner, found crystallized and striated; but no marine exuviae, or organic remains, it is observed, are ever met with in any of the strata. Nor does gypsum accompany it, as is usual in other places, as near Cordova, in Spain, where

rock-salt forms a mountain 500 feet in height, and three miles in circumference, as noticed by Kirwan and Townshend. Jars, the author of the "*Voyages Metallurgiques*," who, it is asserted, has given the most particular account we have of the upper stratum of rock-salt about Northwich, remarks, that "it appears to have been deposited by layers or beds of several colours;" and that "these layers of salt are in such a position, as to lead us to believe that the deposition of it was made in waves, similar to those which are formed on the sea-coast."

This, Mr. Holland says, coincides with an opinion suggested by Mr. Stanley, a friend of his, in regard to the probable origin of the beds of rock-salt, now in existence in this district; who states that rock-salt is there found in several strata, one above the other, with intermediate beds of indurated clay, in the vallies of the Weaver, and those of the other rivers and brooks emptying themselves into it; but that it has never been found so near the surface, as to be above the level of the sea, or beneath any solid rock. If beds of rock-salt are to be considered as so many deposits of salt from sea-water, we must suppose the sea, at some former period, to have occupied the vallies in this county; and that, from time to time, the communications were interrupted between these vallies (then deeper than they are now) and the sea. Earthquakes, or accumulations of sand in the estuaries of the Mersey and the Dee, might, it is contended, have caused the interruptions. Whenever the sea-water in the vallies became separated from the sea, the salt contained in it would subside, by the natural process of evaporation. This, it is supposed, would the more easily have taken place, if, by any subterraneous fermentation, the ground below the water should have been heated. To account for a greater accumulation of salt than the sea-water filling all the lowest parts of the district would contain, we must suppose, it is said, that the obstruction interposed between the vallies and the sea had been repeatedly broken down, and renewed again. Tides, unusually high, might occasionally overcome the resistance of the accumulated sand; and if the intervals between the inundations were only of short duration, a subsidence of salt might take place, equal to the formation of the thickest stratum of the rock-salt now existing. Long intervals between the inundations would admit of an accumulation of clay, and other earthy particles, over the salt thus deposited; and in this manner would be formed a new basis for another stratum of rock-salt to repose upon. Thus, it is thought, the regular and astonishing existence of the salt strata may be accounted for, without necessarily supposing them coeval with the original formation of the earth: but to confirm the theory, it is suggested that much observation and close inquiry into the natural history of the county would be required.

Mr. Holland, however, justly thinks that there are many objections to the theory which supposes the beds of rock-salt, in this district, to have been formed by deposition from the waters of the sea; some of which he states rather for the sake of promoting discussion and inquiry, than of affording any very decided opinion on a matter of so much doubt, uncertainty, and obscurity. Though on making a perpendicular section of the upper bed of rock-salt, an irregular stratification, such as noticed by Jars, may, he says, by frequent accurate examination, be observed, the general appearance of the sides of the openings, whence the rock-salt is taken, is that of a confused and irregular red mass; in which some portions of salt have a greater, others a less, proportionate admixture of earth; while, here and there, they may be seen perfectly pure and transparent. He, therefore, asks, is it likely that this irregularity and confu-

ROCK-SALT

tion would have existed, had the beds of rock-salt in this district been formed by the evaporation of sea-water inundating the land at certain intervals of time, as the above theory supposes? On the contrary, says he, would it not be natural to expect from reasonings, *à priori*, that the salt, thus deposited from sea-water, would be disposed in layers perfectly regular, and differing from one another merely in thickness, or a few other circumstances of inferior moment?

Another fact which, it is supposed, invalidates, in some measure, the notion that the rock-salt has been deposited from the waters of the sea, is the great disproportion of quantity, shewn by analysis to exist, between the earthy salts contained in the brine of this district, and those held in solution by sea-water; the ratio here being as one to ten, or the proportion which the earthy salts bear to the pure muriate of soda in sea-water is ten times greater than that which prevails in the Cheshire brine. The ascertaining of this fact proves, it is supposed, that the rock-salt (from the solution of which the brine is formed) is combined with a much smaller proportion of earthy salts than exists in sea-water; a circumstance difficult to be accounted for, on the supposition that the beds of this substance were formed by the evaporation of the sea-water, occupying the valleys and lowest parts of the land. It must be noticed, however, as worthy of attention, that the earthy salts, intermixed with the rock-salt in the above district, are the same which are held in solution by sea-water, being principally muriated magnesia and sulphate of lime.

There is, however, a still stronger proof, it is supposed, against the notion that the beds of rock-salt in this county are depositions from the sea-water, in the circumstance that no marine exuviae have ever been discovered in the strata. This, it is imagined, would almost indubitably have been the case, had the land been covered with sea-water during a period of sufficient length for the deposition of beds of salt of such prodigious thickness; and the fact, that no such exuviae do actually exist, is supposed in itself sufficient to induce a suspicion that the theory in question cannot be well founded. Other objections too, it is observed, offer themselves to its validity; such as the enormous depth of sea-water necessary to the production of a body of rock-salt forty yards in thickness; the difficulty, if not impossibility, on such principles, of accounting for the formation of the singular insulated mountain of rock-salt at Cordova, in Spain; with others of a more trivial nature, which will readily present themselves in this inquiry.

It is, however, at the same time candidly acknowledged, that there are many facts and circumstances of actual observation, that confer a strong degree of plausibility on the opinion, against which it has been contended. The certainty that the surface of the county was at some former period much lower than it is at present, and the diminution of the thickness of the strata of rock-salt in proportion as they recede from the sea, are circumstances which undoubtedly range themselves on this side of the question: and, upon the whole, it is thought, that it may be doubted whether the theory, which regards the beds of rock-salt as deposits from sea-water, does not accord more exactly with existing appearances, than any other which has been adduced on the matter.

It is supposed that many things, which at first seem objections, may be obviated by a reference to the principles of the Huttonian theory of the earth, and the excellent illustrations of it by professor Playfair. However, in the present state of our knowledge, any opinion formed on the

matter must, it is imagined, from its very nature, be purely theoretical. See *Rock-Salt Pits*.

Rock-Salt Pits, such pits, shafts, mines, or openings, as are dug or made in any other manner in the ground, for the purpose of getting and raising rock-salt from them. Pits of this sort are met with in many parts of the county of Chester, which are wrought to very considerable extents, and are of great importance to the interests of the district in many different ways, as well as to the nation in general, as may be seen under the head *Rock-Salt*.

According to the statement of Mr. Holland, in his Agricultural Survey of the above county, the first bed and pit of salt-rock was found and wrought in Marbury, at a small distance from the town of Northwich, at the depth of about thirty yards from the surface, in the year 1670, when searching for coal. The bed was thirty yards in thickness, and rested upon a stratum or layer of hard clay. In consequence of this discovery, other similar attempts were made; and on sinking shafts or pits any where in the vicinity of it within the space of half a mile, it was found to exist at about the same depth from the surface of the earth, when not prevented from being dug down to by brine-springs or those of common water. This continued the only place in which it was found until the year 1779, when this sort of rock was again met with in searching for brine in the neighbourhood of Lawton, at the depth of about forty-two yards, but only of the thickness of about four feet; there being beneath it a bed of indurated clay ten yards in thickness, which being penetrated through, a second stratum of rock-salt was discovered twelve feet in thickness; and on continuing the sinking of the pit, another layer of indurated clay, fifteen yards in thickness, was passed through; below which appeared a third stratum of rock-salt, which was sunk into not less than twenty-four yards; the lowest fourteen yards, being the purest, or the least mixed with other substances, were the only parts that were wrought.

Until this period, in the neighbourhood of Northwich, no attempts had, however, been made to sink pits in order to find a lower stratum of rock-salt; as the one which had been first met with was so thick, and furnished such an abundant supply for every demand, there could be no other inducement to this than the expectation of meeting with a stratum, at a greater depth, which might contain a less admixture of earthy matters. It would seem, too, that the fear of meeting with springs below, which might impede the working out of the materials from the pits, and even render this wholly impracticable, prevented the proprietors of them from sinking deeper. As, however, no inconvenience or interruption of this nature had occurred, on sinking through different alternate strata of rock-salt and clay at Lawton; and it had been found that there was a lower stratum of rock-salt there, which was more pure than those nearer the surface, the owners of one of the works or pits in this vicinity were induced, a little time after the trials at Lawton, as in 1781, to sink deeper than had yet been done, and to pass through the bed or body of indurated clay lying underneath the rock-salt, which had been so long known and wrought. This indurated clayey material was found to be from ten to eleven yards in thickness; and immediately beneath it a second stratum of rock-salt was met with, the upper part of which differed little in purity from that of the higher stratum or layer of rock; but on penetrating into it to the extent of from twenty to twenty-five yards, it was there found to be much more pure and free from earthy admix-

ture. But it continued to have this increased degree of purity for four or five yards only; while, for fourteen yards still lower, to which depth the pit or shaft was sunk, the proportion of earthy matter was again as large as in the upper part of the stratum. It was therefore, on this account, thought useless to sink the pit to any greater depth. Many other proprietors of pits, shafts, or mines, in the same neighbourhood, it is stated, followed the example which had been thus set them; and penetrated through the bed of indurated clay lying beneath the upper stratum of rock-salt. A second stratum of rock-salt was constantly met with below this; and on passing down into it, the same order of disposition as to purity was observed, as in the pit or mine in which it had been first noticed and examined; and the same has been found to prevail in all the pits, shafts, works, and mines, which have since been sunk in the same vicinity.

It is further noticed, that there is great uniformity in the strata which are passed through in sinking pits for rock-salt or brine; and that they very generally consist of clay and sulphate of lime mixed in various proportions; that of the latter somewhat increasing as the pit, shaft, or work approaches the rock or brine. The workmen distinguish the clay by the appellation of *metal*, giving it the name of red, brown, or blue metal, according to its colour; and the sulphate of lime by that of *plaster*. See QUARRY.

The strata formed by these are, in general, close and compact; allowing very little fresh water to pass through them. In some places, however, they are broken and porous: and they admit so much fresh water into the pit or work, that whenever they have been met with, it has been usual to discontinue any attempts to pass through them in sinking the pits. In these places the workmen call the metal *saggy*. It was thought not only impracticable to overcome a water, which vulgar prejudice had magnified into a great stream running under ground; but it was believed, even if the sinking could be continued below this, that the water could not be kept out of the pit, shaft, or work, and that it would either weaken the brine so as to destroy its value, or would find its way into the cavity of any rock, pit, or mine which might be found below it. Later experience, it is said, has proved, that these ideas were not altogether well founded. A few years ago an attempt was made in Witton to pass through this porous stratum, in order to get to the brine. It was met with about twenty-eight yards from the surface; the thickness of it was about thirteen feet; and the quantity of water, which was forced through it into the pit or shaft, was three hundred and sixty gallons a minute. By means of a steam-engine, the sinkers were enabled to pass through this water; to fix a gauge or curb a few yards below it, in a stratum of indurated clay; and thence to bring up a wooden frame, supporting a wall of puddled earth twelve inches thick, by which the access of the fresh water into the pit or shaft was in a great degree prevented, and an opportunity given to pass down to the brine below. A shaft was afterwards sunk through this porous stratum, for the purpose of obtaining rock-salt; which object was, after a short time, defeated, by the influx of brine into the shaft at the surface of the upper stratum of rock-salt; an accident originating in a cause completely distinct from the fresh water in the porous stratum or bed. An exact section of the different strata sunk through in reaching the second bed of rock-salt in the pit at Witton, near Northwich, is given by Mr. Holland in the above report; and all the strata in

the neighbourhood of the last town are supposed to have nearly a similar disposition. The inclination of them in the pit or shaft at the above place was from north-west to south-east; and the dip about one yard in nine. The stratum through which the fresh water flowed is shewn, and the level it found, it is said, was sixteen yards from the surface, which, it is remarked, nearly corresponds with that of the brook below. The line of separation between the lowest stratum of earth, and the first of rock-salt, is very exactly defined; they are perfectly distinct, and do not at all run into each other. It is farther noticed, that in carrying a horizontal tunnel for one hundred yards along the upper stratum of rock-salt, this was found to be irregular and unequal on its surface; the irregularities in a great measure corresponding with those on the surface of the ground above.

The highest bed or body of rock-salt in the pits near Northwich is the thickest in those situated the most to the north-east, gradually declining in thickness towards the south-west, so as to lose one-sixth of it in the course of about a mile. It decreases from about thirty yards in those the farthest to the north-east, to about twenty-five in that the most to the south-west.

A singular appearance is remarked to present itself on making a horizontal section of the stratum of rock-salt in the pits: on the whole of the surface made by such a section, various figures, it is said, may be observed, differing in form and size, some of them being nearly circular, others approaching more to an oval form, while in many an irregular pentagon may be traced. Some of them are not more than two or three feet in diameter; others are ten or twelve feet. The lines which form the boundaries of these figures are white, and from two to five or six inches wide. On examining these appearances, they are found, it is said, to be owing to the rock-salt, in the white lines forming the divisions of the figures, being perfectly pure, and free from earthy admixture. When combined with the salt, having earth in various proportions mixed with it, a general effect is produced, it is said, not very distinctly resembling mosaic work. This disposition is uniformly observed, it is said, throughout the whole thickness of the stratum of rock-salt; and that in whatever part of it such a section as the above is made, similar appearances are met with. To what cause it has been owing that the rock-salt has been deposited in this singular manner, it is thought difficult to conceive. The whole stratum of rock-salt may, it is supposed, be compared to a mass of basaltic columns; the lines of separation in each pillar being marked by the pure and transparent white salt. These appearances, it is noticed, afford several grounds for inferences favourable to the theory of the earth mentioned under the head rock-salt, to the illustration of it. See *Rock-Salt*.

It is likewise further observed, that the division betwixt the lower portion of the upper bed of rock-salt, and the indurated clay or stone beneath it, in pits of this kind, is as exactly defined, as that between the upper portion of it and the earth above. That in passing through this stone small veins of rock-salt are met with, here and there running in it, in various directions; and that wherever there has been any little crevice in it, it is found filled up with rock-salt, to which the clay and oxyd of iron have given a deep red tinge. The thickness of this stratum of stone is said to be uniformly found to be from ten to eleven yards; and the lower part of it is as distinct from the second bed of rock-salt, as its upper part is from the first: also that its termination is equally abrupt or sudden.

And that the perpendicular section of the second bed of rock-salt varies little from that of the upper bed, till it has been penetrated about twenty yards from the surface, when it assumes a more stratified appearance, and is here found, as already noticed, to have a much smaller proportion of earth combined with the muriate of soda. A section of this stratum, similar to the above, displays the same figured appearance in the roof of the pit, as that of the upper stratum.

In the very instructive report mentioned above, the writer has given a coloured representation of the roofing of a rock-salt pit, and another of the part where the lower surface of the upper bed of rock-salt joins the inferior clayey or other strata. These, as well as other matters in that work, are particularly worthy of the attention of the inquirer on this subject.

But though beds of this sort of material have been occasionally met with in some other parts of the same district, they have not been wrought, principally on account of the want of water carriage: as the working of those pits at Lawton was soon discontinued, it is now only from the pits in the neighbourhood of the town of Northwich that rock-salt is procured. At this time there are ten or twelve in number; at all of which the rock is wrought in the lower stratum or bed only. The pits or shafts are for the most part square, and built or formed with timber; but there is one at the distance of about a mile from the town of Northwich, which is of a circular form, and built in brick-work.

In regard to the manner of working the pits or mines, there is nothing of any very great interest or moment to be noticed. By means of boring and blasting the rocky stratum, and the use of wedges with the different mechanical instruments employed in mining, the salt-rock is separated, so as to be raised in large masses, which vary in form and purity. However, before any considerable extension of the workings in the pits, in any particular direc-

tion, takes place, care is taken to make sure of a good safe open roofing for the cavity which is to be formed in getting out the rock. In doing this the workmen make use of pointed implements of the common pick kind, working the materials out in an horizontal manner, so as to form an excavation in the rock, and making it in as simple a way as possible, or as the work will admit. In consequence, however, of its being situated a few feet above the purer part of the stratum, the rock which is obtained during this process is commonly of inferior quality, and is, for the most part, made use of in the refineries. The depth of the workings from the excavations or roofings, it is remarked, depends in a great measure upon the nature of the stratum, and the proportion of it occupied by the rock of the purer quality, or, as it is termed, *Prussian rock*. Fifteen or sixteen feet may perhaps, however, be taken, it is thought, as the average depth of the workings in the pits. The cavity thus formed presents a striking appearance; and when illuminated by candles fixed in the rock, the effect, it is asserted, is highly brilliant. In some of the pits or shafts, the excavated roofs are supported and kept up by pillars eight or ten yards square, which are in general arranged with a degree of irregularity: others are worked out in aisles; the choice here however seems to be wholly arbitrary, depending on the men who are employed in the work. Until these few late years, horse labour was wholly employed in raising rock-salt from the pits and shafts about the town of Northwich; but this method has now, in some measure, given way to the best kind of steam-engine, which has been substituted in its stead, in many of them with very great advantage. In others, however, horse labour is still continued to be made use of for this purpose. The men who are employed in working the rock-salt pits, have their pay by the quantity of the material which they raise, having in general somewhat less than half a crown for the ton weight, they finding tools and every thing else necessary for the work.

Roll

ROLL, in the *Manufactories*, something wound and folded up in a cylindrical form.

Few stuffs are made in rolls, except lappins, gauzes, and crapes, which are apt to break, and take plaits not easy to be got out, if folded otherwise. Ribbands, however, and laces, galloons, and paduas of all kinds, are thus rolled.

The ancients made all their books up in form of rolls, or little columns; and, in Cicero's time, the libraries consisted wholly of those rolls. The dearth of parchment, and the cheapness of papyrus, of which the rolls were

made, was the reason that scarcely any but paper rolls were used.

Vossius says, they pasted several sheets end to end, when filled on one side, and rolled them up together, beginning with the last, which they called *umbilicus*, and to which they fastened an ivory or boxen stick, to sustain the roll. To the other extremity they pasted a piece of parchment, to cover and preserve it.

These rolls were placed in the libraries perpendicularly to the horizon. The Jews still preserve the ancient usage of rolls for the books they read in the synagogues.

Rolling-mill

ROLLING-Mill, in *Metallurgy*, and particularly in the *Iron Manufacture*, is a mill for reducing masses of iron or other metals into even parallel bars, or flat thin plates: this is effected by passing the metal, whilst red-hot, between two cylindrical rollers of iron or steel, which are put in motion by the power of the mill; and being so mounted in a strong metal frame, that they cannot recede from each other, they compress the metal which is passed between them, and reduce it to a thickness equal to the space between their surfaces.

It requires a most enormous power to put in motion the rollers which are employed for laminating iron in the large way; and for this reason, the greatest number of rolling-mills are situated upon the banks of rivers which have the advantage of a sufficient fall to turn the machinery. Of late years, the improvements of steam-engines have been carried to such a high perfection, as to put them on a par with water, for most purposes, and particularly for rolling-mills, as the waste heat of the furnaces used for heating the metal may be employed, in part, to raise steam for the engines which turn the rollers.

Rolling-mills were not very generally used in the iron manufacture till within these sixty years. The old mills which were first used are extremely simple; two separate water-wheels are placed on the opposite sides of the mill, with their axles in the same direction, but at different heights, so that one wheel can be connected with the upper, and the other with the lower roller: it therefore requires the two wheels to have the water delivered at opposite sides, to make them revolve in different directions, in order that the upper surface of the lower roller, and the under surface of the upper roller, may move in the same direction, and pass the iron between them. The construction of the rollers generally used in such mills is shewn in *figs. 3, 5, and 6, of Plate V. Iron Manufacture*, except that the two rollers, *F* and *G*, are there shewn with equal pinions, *d* and *e*, fixed upon the ends of their pivots, to compel the two to revolve equally together; whereas, in the mills with two separate wheels, no provision is made to ensure the equal motion of the two. The gudgeons, or necks, of the lower roller, *G*, are supported in brasses, fitted into strong carriages of iron *E, E*, which have holes through their ends, to receive four strong iron bolts, *A A, B B*; these stand perpendicular, and form the frame, to retain the rollers at the proper distance, being fitted through the carriages *E* with heads below, so that they cannot draw out. The upper ends of the bolts are cut with screws, upon which nuts, *a, a*, are fitted; and these being turned round by iron handles or wrenches, screw down the pieces *D, D*, and advance the rollers nearer together; or, by a contrary motion, increase the distance between them: *i* (*fig. 6*) is a strong iron bar, extended from one bolt, *A*, to the other, *B*, and fixed fast; it supports an iron plate, forming a kind of table before the rollers, to guide the iron through them. The rollers have square heads upon the ends of their gudgeons; and upon these squares, large cast-iron sockets or boxes, as *L*, are fitted, and these, at the other ends, are fitted upon similar squares on the ends of the water-wheel axis. A little play or looseness is admitted in all these squares, because the upper roller is set at different heights, according to the thickness of the work which is to be rolled between them: this play is required to

allow the rollers to move freely, when they are not exactly in the line of the water-wheel axis: it is to accommodate this circumstance that the principal care is required in constructing a rolling-mill. Our readers will gain a good idea of the best proportions of a mill, with two independent water-wheels, from the following directions for building one in Northumberland, which were given by Mr. Smeaton near 40 years ago. The two water-wheels are to be under-shot, and of different sizes, *viz.* 15 ft. 4 in. and 14 ft. 8 in., the mean diameter being 15 ft. The breadths in their float-boards are to be three feet each, the small wheel being laid lower than the other by seven inches: this, with the differences of their diameters, will make the centre of the large wheel 11 inches higher than the other. The different heights of the crowns of the falls or breaks, down which the water descends to act upon the wheels, and the positions of the water-shuttles, are to be so adjusted, that the gates or shuttles being equally drawn up by their starts, the wheels will, as near as possible, revolve in equal times, and with equal power. The rings of the water-wheels are to be made of cast iron, that their weight may act as flies: the ring of the lesser wheel is to be made six inches in thickness by six inches deep, while that of the larger is to be only five by six. The greater quantity of matter in the lesser wheel, therefore, will give it nearly the same momentum as the larger wheel.

The rings of the water-wheels are each to be formed by eight pieces or fellys, the exterior circle of the greater wheel being thirteen feet diameter, and that of the less twelve feet four inches: the length of the fellys is to be about half an inch shorter than their true length, in order to admit an oak wedge of one inch thick to be introduced into every joint after the rings are sewed together by the joint-plates of wrought iron, which unite the fellys. These plates are to lay upon the plain surface of the felly, and not to be let in as the common wooden rings of water-wheels, in order that the oak wedges may completely fill the joints at the ends of the fellys. The wheels are to have wooden arms, and it must be observed, that the mortises through each of the iron fellys, for receiving the ends of the arms of the wheels, are to be about two inches and a half in width, and that they are to be a little dove-tailed, in their length only, so that the mortises being longer on the outside of the ring, and the wood of the arm being spread into them with wedges, will produce firm ties to the centre; but as a farther security, pins are to be put in after the wedging is completed. The mortises in the rings for the starts, which support the float-boards, are to be four inches by two, without dove-tailing, or rather they should be larger outside than inside. The breast or float-boards will fix by nails into the joints and arms, where they fall; but that the breast-boards for the intermediate floats may also have a fastening, holes of about one inch diameter, and about four inches deep, must be cast in the ring, at the places for every other float; these holes, being filled up with pieces of oak, will afford places to drive the nails for securing the boards. The axles of the water-wheel are to be of cast-iron, with flanches to screw the arms of the wheel against. The total length of each axis is to be seven feet one inch, and the diameter throughout the axis is to be a circle of nine inches. The manner of fixing the arms upon flanches is to be found in *Plate XXXIV. Mechanics*, in our article *MILL*.

The brasses upon which the necks of the water-wheel axles are supported, are intended to be let into cast-iron stocks, which are again supported upon wooden bed-planks, and those upon the cap-stones of the walls, which (under these at least) are supposed to reach all across the thickness of the walls, those necks being first truly and smoothly turned; at each end, beyond the neck, is formed an astragal or moulding, to keep the wheel in its place from moving endways. The ends of the axis are terminated by an indented head, shaped somewhat like a square citadel in fortification, and an iron box is fitted upon this to communicate the motion to the rollers, the surface lines of the indented head being formed a little rounding, that the box may not only be certain of taking its bearing in the middle, but likewise be capable of complying with the motion of the rollers: and in order to give still more liberty, the end of the box which is farthest from the water-wheel, is formed into a square of eight inches, which is again surrounded by another box, whose external surface is round. This box is formed at the end of a round spindle or axis three feet long, and terminated at the other end with a square of eight inches, which enters one end of a square box, and at its other end receives the square of the roller, supposed to be of six inches, but may be of any other size which is thought necessary. It is to be noted, that all the squares are to be made larger than those of the rollers, in order that they may wear longer; and all the insertions are to be less than those at the end of the water-wheel axles, that the axis may not be rendered useless by the wear or failure of the citadel heads which are introduced, as they are expected to last many years; and if any thing should happen to them, the axes are made alike on both sides of the water-wheels, that they may change ends; therefore, there is nothing of consequence likely to fail by wear or breakage, except the smaller intermediate work between the axis and the rolls, which is easily replaced. Holes are to be made through the boxes and joint parts for iron bolts to pass through rather loosely, so as to prevent the boxes and squares separating, but not to confine the joints from yielding to the motion of the rolls. The water-wheels are supposed to be closely adapted to their conduits, and their axes to remain immovable as to height, at the difference of eleven inches in level, while the rolls are supposed to vary in their diameter from twelve inches to nine. This will be allowed for, by the distance that the squares upon the rolls are from the end of the axis; for though the house is supposed no more than ten feet wide between the walls, the distance between the middle of the citadel heads at the end of the water-wheel axis, and the middle of the squares of the rolls respectively, is upwards of four feet; and in that length no less than four joints are introduced, every one of which complying a little, a small difference in the height of the roll will produce no sensible difference in the communication of the motion from that of a right line; all the joints being kept oiled or greased, which will be not less proper on that account than to keep the parts from wearing. In order to preserve the directions as near as possible to a right line, Mr. Smeaton proposes that the lower roll shall be placed originally half an inch below the centre of the axis which turns it: suppose the rolls were first made of twelve inches diameter, while the difference of the height of the axis is only eleven, the upper roll will be just half an inch too high, so that the compliance in each will be equal, and no more than half an inch in four feet length. Thus it appears, that when the rolls are reduced by wearing from twelve inches to eleven each, then the upper roll as well as the lower will be half an inch too low for its axis; still

neither will need to comply or vacillate more than half an inch. The roll being now of a just diameter to answer the different heights of the axis, let the lower roll be raised to its just height, and then both the rolls will work true till they are further reduced; but when they become reduced to ten inches and a half diameter, the upper roll will become half an inch too low; then raise the under roll half an inch above the line, and the upper roll will then be truly in the line; so that when the upper roll is come down to be half an inch below the line, the rolls will be reduced to ten inches; then raising the under roll a quarter of an inch more, it will be three quarters above the line, and the upper roll will be a quarter of an inch under the line; and when it comes down to three quarters below the line, the rolls will be reduced to nine inches and a half; therefore, lastly, raise the under roll another quarter, so as to be an inch above the line, and the upper roll will be reduced to half an inch below it, so that when it is come down to an inch below it, the rolls will be reduced to nine inches. In this way the departure of the rolls from a right line will never become more than half an inch, while they are reducing from twelve to ten inches; nor more than three quarters, while they are reducing from ten to nine and a half inches; at the worst they will be no more than an inch, while they are reducing from nine and a half to nine inches. The greatest inequality is purposely made at this place, both because the purchase of the wheels is then greatest and most able to overcome an addition of friction, and because the time that they will continue in this state is the least. If the axles are placed at ten and a half inches distance instead of eleven, the vacillation each way will never exceed three quarters of an inch; nor more than one inch to reduce the rolls to eight and a half diameter.

The raising of the under roll is not to be done by raising the whole of the bed of the roller-frame; this is to be set originally half an inch lower than the true line; and when the lower roll requires raising, it is to be effected by putting iron plates under the carriages of the lower roll gudgeons, so that they will stand as much higher than before, and not to make the several rises by additional plates, but to have plates of the different gages, so that each will lay in one solid piece.

Mills, on this construction, are still used in many iron-works for rolling coarse iron bars, but are unfit for any better purpose, from the difficulty of adjusting the two water-wheels to an equal velocity; and if one roller moves quicker than the other, the metal becomes more extended that side than upon the other, and is thus rendered uneven. Another defect is, the want of proper fly-wheels to regulate the mill; for the cast-iron rims to the water-wheels by no means answers the purpose of fly-wheels, unless they are made to revolve so quickly that the water loses much of its effect upon the floats. Fly-wheels are, perhaps, more useful for rolling than in any other kind of mills, because the resistance to be overcome is so variable; being at one moment very great for a large piece of iron, then smaller whilst it is passed through a second time, because the iron is to be less reduced: and in the interval of returning the iron, to put it through again, there is no other resistance than that of the friction of the machinery. Again, when the iron has been passed through several times, the resistance is greatest of all, because the metal has become harder, both by the compression it has undergone, and from being gradually cooled; also, the metal, being thinner, will not yield so readily to the pressure, as when in a larger mass. By the proper addition of a heavy fly-wheel, great advantages, in point of power, are gained, as it tends to

equalize all these irregularities; and in every interval, when the resistance is removed, the water-wheel gives a rapid motion to the fly, the force of which will be returned when the work is applied: in such a mill, if the workmen have an extraordinary large piece of metal to roll, they suffer the mill to work for a few seconds without any resistance, then putting in the iron, it is carried through at once by the momentum of the fly, though requiring a power far beyond the ordinary force of the water-wheel. The most approved method of applying a fly-wheel to a rolling-mill, is to have a large cog-wheel upon the axis of the water-wheel, to give motion to a pinion, upon the axis of which a heavy iron fly-wheel is fixed: the wheel and pinion are of such a size as to make the fly revolve about three times to one of the water-wheel: at the opposite side of the great cog-wheel another pinion, of about half its size, is placed, and to the extremity of its axis produced, the rollers are connected, the two rollers being made to turn together by means of pinions upon the ends of their gudgeons, in the manner shewn at *d e*, *fig. 6. Plate V.* If more than one pair of rollers is to be worked, a cog-wheel is fixed upon the axis which turns the rollers, and works another equal wheel upon the axis of the second pair, placed parallel to the former; in this case the lengths of the two axes must be different, so that the lines in which the bars will come through the different rollers, will not interfere with each other, but leave sufficient room between for the men to work. In most common mills, rollers, such as are represented at *figs. 3, 5, 6, of Plate V.* are employed; but to these there are some objections; first, the four nuts *a, a*, cannot all be turned at once with such precision as to bring the upper roller exactly parallel to the other; the means the workmen use for this, is to have a small iron wrench, or handle, fitted upon two of the nuts, *a, a*, and these they turn round a small quantity every time the metal has passed through, in the interval whilst it is returned to be put through again. The workman who stands in front to introduce the metal between the rollers, turns the nut on his left-hand side which is nearest to him; whilst his comrade, who receives the metal, and hands it back again to him over the roller, turns the nut on the opposite corner of the frame: by this means, as only two, instead of four, of the nuts are turned, the pieces *D* are constantly put out of the horizontal position, in which alone they can take a proper bearing; also, in these frames there is no support for the weight of the upper roll; but when there is no metal beneath it, it falls down, and rests upon the other; when the metal is suddenly introduced, it lifts the roll up to its bearing with a jerk, which endangers the breaking of some of the parts, and generally causes the nuts to start a little before they settle themselves to the strain. In the modern mills, the frames for the rollers are made of cast-iron, as shewn at *figs. 1 and 2. Plate V.* The checks, *A*, are cast in one piece, and form a bed for the reception of the brads of the lower roller *H*; a piece, *C*, is fitted upon the top of the cast-iron checks, and is held down by two strong wrought-iron bolts, with nuts, *a, b*, to screw it down, and regulate the distance between the two rollers, the gudgeon of the upper roller, *G*, being confined by a brad let into the piece *C*, but to bear it up from falling: when there is no iron between the two rollers, another brad is placed beneath the gudgeon, *G*, and suspended by bolts, *d, d*, from the piece *C*; by this means the two rollers are retained always at a proper distance asunder. The two standards *A, B, fig. 2*, at the opposite ends of the rollers, have broad feet at bottom, by means of which they are bolted down to massive ground-fills, which extend all across the mill-house. The rollers *E* and *F* are

caused to move together equably by means of pinions *a, b*, which, that they may work well, are made with accurate teeth, of not more than $1\frac{1}{2}$ or 2 inches pitch, or distance asunder; and, to give the requisite strength, they are made of considerable breadth, as the figure shews. Two large flat iron plates, *I* and *K*, are screwed to the two standards, both to strengthen them, and to form a table, upon which the masses to be rolled are laid to be presented to the rollers, and having passed through, are received on that at the opposite side.

The rollers shewn in *figs. 1 and 2*, have a number of grooves in them, which being opposite to each other, leave openings of a determinate figure for the purpose of rolling square bars, with the angles upwards; they do not therefore require to be adjusted in distance, as other plain rollers do, but are always, after the first erection, retained at the same distance; in this case the pinions *a* and *b* serve very well to connect the motions of two rollers together; but when the rollers are required to be adjusted during the working, as in the *Plate Rollers, fig. 6*, the pinions must necessarily have very coarse and long cogs, that they may not be so much affected by increasing or diminishing the distance between their centres; in this case they work very indifferently, and frequently break by the awkward manner in which such coarse teeth always meet each other when upon wheels or pinions of small radius, particularly when the proper distance between their centres is not preserved. As a partial remedy for this difficulty, the pinions are, in some mills, made very broad, with fine teeth, and mounted in a separate frame, exactly similar, except in its strength, to that of the rollers; this is placed at a distance of three or four feet from the rollers; then a coupling, or short shaft, being interposed between the squares at the ends of the axis of the pinions, and those of the rollers, they permit the latter to be adjusted without disturbing the pinions; and the length of the shafts will accommodate for the differences between them.

In *Plate IV. of Iron Manufacture*, we have given three figures of a very capital rolling-mill in Messrs. Walker's extensive iron-works at Rotherham, in Yorkshire, where they have several mills worked by the same river. The one in question is employed in reducing iron to small rods for nail-making, by first rolling the pieces to flat bars, and then passing them through a pair of flitting rollers, which divides each into several small square rods: it is, therefore, much smaller in its dimensions than the great mills used for rolling thick iron plate; but we have selected it on account of the arrangement of its wheels, which renders it superior to the mills in common use, as it works without the pinions of which we have spoken. *A A*, in the plan, (*fig. 1.*) is the water-wheel, 17 feet diameter, and five feet six inches broad: it is of the under-shot or rather breast-kind, the water being delivered below the centre, but confined to act upon the wheel by a breast of masonry, curved to correspond with the wheel very exactly. The pivots or gudgeons, *n*, of its axis rest on bearings, supported by the walls *N*. At one end of the axis a clutch-piece, *M*, is fixed, to give motion to a second axis *k*, which, being in the same line as that of the water-wheel, may be considered as a continuation thereof. It is carried under the floor of the mill. It has two large cog-wheels, one marked *b*, and another of the same dimensions at the opposite end, which is only seen in *fig. 2*, as it is concealed in *fig. 1*, beneath the wheel *f*, which it turns. The first of these wheels, *b*, gives motion to two wheels, *a* and *c*, which are on the axes *I* and *H*, and give motion to the lower of each of the two pair of rollers, situated in the frames at *E F* and *C D*. This wheel-work is shewn in

fig. 3. The wheel at the other end of the shaft, *k*, (see *fig. 2.*) turns the wheel *f*, situated directly above it; and this gives motion to two wheels, *e* and *g*, of the same dimensions as *a* and *c*. Their axles, *L* and *K*, are connected with the upper of each pair of the rollers. By the introduction of the wheel *f*, the small wheels, *e* and *g*, are made to revolve in a contrary direction to the wheels *a* and *c*; and, at the same time, the centres of the former are raised a sufficient height above the latter, to allow for the difference in height of the centres of the upper and lower rollers of each pair. The coupling-boxes, *L*, *K* and *p*, *p*, which unite the axles of the wheels to their respective rollers, have sufficient play in the joints to allow for that small deviation which takes place in separating the rollers, to adjust them to different thicknesses of the metal they are intended to roll; though these shanks should be represented longer than the limits of our plate have allowed, the space between the frames for the wheels being in reality eight feet, instead of five feet nine inches, as given in the drawing.

By this arrangement of the wheels of the mill, the contrary motions of the two rollers are communicated from the same water-wheel, without the intervention of small pinions, which, in works requiring such heavy strains as that of rolling iron, always work with difficulty and enormous friction; so that they break and wear out constantly, making great interruptions to the work. In the present instance, the wheels are all of considerable size, and, therefore, transmit the power more equably, at the same time that they give the two rollers precisely the same velocity, which is a circumstance of some importance in making good rolling for plates or bars, which will be irregular, if one roller turns faster than the other, in consequence of one side of the metal being more expanded. The framing of the mill (*Plate IV.*) is very clearly expressed by the drawing. The axles *H* and *I*, of the wheels *a* and *c*, are supported in bearings, screwed down to iron frames, which are securely fixed to the solid masonry. On the other side, the iron frame, *O O*, is erected to support the axles of the wheel *L K*, and also that of the wheel *f*, as shewn in *fig. 2.* The main axis *k*, and the wheels upon it, are carried under ground, and supported on the walls, as shewn by the plan. The roller-frames, *CD* and *EF*, (*fig. 1.*) are fixed down upon strong beams, extended across from the frame, *O*, to the frame on the opposite side. The position of one of these beams is shewn by dotted lines on the right-hand side, in *fig. 1.* The rollers, *C*, *D*, are exactly the same as shewn in *Plate V. figs. 3, 5, and 6*, except that the pinions, *d* and *e*, are omitted, being unnecessary, from the arrangement of the wheels, which we have described. The other rollers at *EF* are made on a very different construction, and are called slitters, because they slit or cut up a bar of iron into several small square bars, of a size proper for nail-makers, or to form hoops for barrels. These slitters consist of two strong axles, mounted in a similar frame to the other rollers; but instead of carrying plain cylindrical rollers, they have rollers composed of steel rims or edges, of the same breadth as the rods they are to slit, and leaving between them deep grooves. The two slitters, or cutters, are so placed in their frame, that the rims of one roller will enter into the grooves between the rims of the other. This will be understood by an examination of *fig. 4. Plate V.*; though the rollers there shewn are for a totally different purpose, still the manner in which the rings of one roller enter the grooves of the other is the same as the slitters: but the proportion of breadth is different, the slitters being made with grooves of half an inch, three quarters, or one inch wide, and many intermediate sizes, corresponding to the

rods to be cut; and they are not made from a solid roller, but are formed of separate circular plates of steel of the just thickness, fitted side by side upon the axis, with circular iron plates of equal thickness between them, which form the spaces; and being of a less diameter than the steel plates, or cutters, they leave deep grooves between the edges. A number of crooked guide-bars are extended across the frame, and pass through the grooves, between the cutters; but lying at the very bottom of the grooves, and not being very thick, they do not fill up the grooves, the circles of the cutters projecting through these bars, which appear like a grate, and one is applied to each roller. Those which are called the guides of the slitters are intended to prevent the iron adhering in the grooves between the rims, or cutters, when pressed down into them; for the action of the slitters is to divide the iron which is passed through them into separate pieces, by the rim of one roller (for instance, the lower) forcing one piece of the bar down into the groove of the lower roller, whilst the adjacent part is forced up, by the rim of the lower roller, into the groove of the upper: the bar is thus divided into as many rods as there are grooves in the width which it covers. The angle at which the circles of the cutters intersect each other, is that in which the edges of a pair of shears are found the most favourable for cutting; and the slitters cut upon the same principle, but with several edges at the same time.

A rolling-mill generally contains a pair of shears, of a sufficient strength to clip off the ends of the largest iron bars, to reduce them to lengths or pieces of a sufficient size for laminating into thin plates. These are made different from other kinds of shears, in the circumstance that the cutting parts, or edges, are situated between the centre pin or joint, and the part or handle where the power is applied: the latter is of great strength, and made exceeding strong in iron. The shears are fixed in a vertical position, the upper blade being firmly fixed by the framing, and the lower one, which is the long lever, is lifted up by the mill when the cut is to be made; therefore it descends when the shears are to open, and its own weight is sufficient for that purpose. The frame consists of a very large and thick iron plate, which is securely bolted down to the foundations: at one end is an upright, which has a groove through it, to receive the moving blade, and guide it; also the end of the handle of the stationary or upper blade is supported by the upper end of this upright. The joint-pin of the two blades is supported in a strong socket, or iron frame, also erected from the same large plate, which carries the upright guide at its other end. The two blades, therefore, lie side by side, and having cutters, or blades, of steel, let into the adjacent sides of the iron levers or blades, the edges of these pass by each other when the cut is made, and will thus cut any thing which is interposed between them, in the same manner as shears or scissars; and in this circumstance is their only resemblance to those instruments. The lower or moving blade, which is a long lever, rests at the extremity, upon the periphery of an elliptical wheel, or cam, (*figs. 1, and 3.*) fixed upon the axis, *I*, of the rollers, (or, in other cases, upon the shaft of the water-wheel,) in an excentric manner, so that, in turning round, it will lift up the lever, and close the shears; but when its opposite or shortest radius comes beneath the lever, it is suffered to descend, and open the blades. At this moment the workman introduces the end of the iron-bar between the blades, pushing the end of it up to a stop, which regulates the length to be cut off; then as the cam turns, it closes the blades, and cuts at once through the bar, although some of the largest are as much as three inches broad, and an inch thick.

Rollers are usually made of cast-iron, and are very exactly turned on their surfaces, and also their necks, that they may turn truly when put in their places. The most common way of turning them is, first to mount the roller in a strong turning lathe, by holes or centre points made in its ends; then to turn the two necks truly cylindrical; and afterwards putting the roller in its proper place in the roller-frame, and placing brasses over the necks, they are held down by blocks, fitted under the pieces which retain the gudgeons of the upper roller: in this situation it is put in motion by the mill, and a bar of iron being fixed up for a rest, the surface of the roll is turned true, in the same manner as if it was in a lathe, and will be certain to be exact, being formed from the same necks on which it is afterwards to work. In casting a roller, the mould should always be placed at a considerable depth beneath the orifice where the metal is poured in, so that the pressure of a column of the fluid metal may be obtained to consolidate the casting, and render it free from those air-holes, or porous places, which will sometimes occur in metals cast without the pressure of a column. The long piece of metal which filled the aperture through which the metal ran, is left adhering to the roller, and is cut off afterwards. This is the same mode of casting that is practised for *cannon* (see that article). Case-hardened rollers must be used when it is required to have a very fair surface; viz. for such purposes as rolling iron to make thin plates for tinning; also the large rollers for gold or silver, such as are now used in the Royal Mint; rollers for making tin-foil, steel-plate for saws, and for many other purposes. These rollers are not hardened by a subsequent process, as in case-hardening wrought iron, but are cast in that state. This is effected by employing iron moulds: a cast-iron cylinder of three inches thick, and its diameter equal to that of the roller, is bored out with great accuracy, and fitted with ends proper to form moulds for the necks required at each end of the roller; this is buried in the sand of the foundry, and when the metal is run into it, the rapid transmission of the heat through the iron mould causes the metal which is in contact with it to cool sooner than the other parts of the mass, and renders the surface of the roller very hard. In turning a roller of this kind, the centres must be chosen so that the circumference turns as true as it will admit, and then a very small quantity being taken off, will render it perfect: this care should be taken for two reasons; first, that less will be required to be removed to make it true, which is a difficult operation, as only the best steel tools will cut it; also, that if the metal is unequally reduced, or more on one side than the other, the hardest part will there be cut away, and the roller will have a hard and a soft side, and soon wear out of the circular figure, and require a second turning. The less metal there is turned off a case-hardened roller the better it will be, because the hard part is only a case of slight thickness, and most hard at the surface.

The operation of the rolling-mill is so simple, as scarcely to require any description: the metal is heated in reverberating furnaces when it is in large masses, and for smaller pieces a kind of oven is used, in which the coals are laid on the bottom or floor of the oven without any grate-bars, and therefore the draft of air being less rapid, it gives a slight, but very regular heat, which rises to a bright red, but no farther, and therefore it does not waste the iron by burning it to scales, as a greater heat and current of air will do. This oven is proper for heating plates, hoops, or small bars, to be rolled a second and third time: but for rolling large masses, a strong welding heat is requisite, that the metal may be consolidated, and all flaws or cracks securely closed. The

reverberating furnace is used for this purpose; it is made the same as an air-furnace for melting large quantities of iron, except that the floor is horizontal; indeed it is as near as possible similar to the balling furnace. (See *Plate II. Iron Manufacture.*) The furnaces are placed as near as convenient to the rollers.

The iron, being heated in the furnace to the proper degree for the purpose which is intended, is taken out by a pair of pincers, the mill put in motion by drawing the shuttle, and the iron is presented to the rollers, which are previously adjusted to the thickness of the piece which is to be passed. If this is not attended to, and the workmen attempt to reduce the iron too much at one time, there is danger of breaking some of the machinery, or of flopping the mill whilst the iron is only half passed through: this is a disagreeable accident, as it will require four or five men, with an enormous wrench applied to the nuts of the roller, to turn them back sufficiently to relieve the rollers, so forcibly are the ferrets pressed whilst the iron is passing through: this is indeed evinced by the circumstance of solid cast-iron rollers, of ten inches in diameter, being sometimes broken in the middle; and the necks of eight and nine inches are frequently snapped. When the iron is placed on the shelf or table before them, their motion will draw it through, and as they cannot recede from each other, because of the nuts of the bolts, the metal is reduced to the exact thickness of the space between them, increasing in length, but not at all in breadth: the iron is caught by another workman behind the rollers, and returned over the top roller to the first man, who puts it through again, first giving the handles of the nuts a small turn, to bring the rolls nearer together. In this manner it is repeatedly rolled, till it is reduced to any required length and thickness, but the breadth is not at all increased by rolling; and if it is required to increase the breadth, it is done by putting the iron obliquely through the rollers; or if a great increase is wanted, the iron is put through breadthwise two or three times, till it is extended to the length of a gauge which the workman has marked upon the table in front.

Rolling of black Plate, such as is used for making the boilers of steam-engines, tanks, or other large vessels, in wrought iron. Such plates, when large, and of considerable thickness, are rolled from the blooms, or half blooms, which are made under the forge-hammer. These blooms, which are also called slabs, are nearly the length of the intended plate; their breadth about one-half or one-third as much as their length, and of a thickness to contain as much metal as will make two, three, or four plates. These pieces, when heated to a white heat, are presented breadthwise to the rollers, and passed through several times at the same heat, until what was the breadth of the bloom, being extended two or three times as great, becomes equal to its length. The thick square plate, thus formed, is now cut up by the shears across into two or three pieces, of about the same size as the first, but in a direction which will make what was the length of the first piece to be the breadth of the second. These pieces, being heated and rolled again, become extended to the size of the required plates: the reason of thus dividing the operation is, that the rolling only extends the metal in the direction in which it moves, and not at all in breadth: by this means, the particles of iron being drawn by the sides of one another, acquire something of a fibrous texture, or an approach thereto, which is desirable in bars, rods, and hoops, but not at all in plate, as it should be equally strong in either direction; therefore, by rolling it first one way, and then the other, the grain, as far as it is produced at all, is in both directions. There is no doubt that better plate would

be made, if the slabs or original pieces were cut to the proper proportions of length and breadth, and of a thickness to form only one piece; then rolling it alternately length and breadth ways every time it is passed between the rolls, and continuing this till the plate is finished, at one heat; a better grain or texture will be thus acquired, because in the former method it will be weaker one way, having something of a grain in the direction of the last rolling.

Rolling iron Plates which are to be Tinned.—These are made from the best English iron, and some of the very thinnest from foreign iron; the bars are drawn out, by the forge hammer, to five inches broad, and half an inch thick, and are cut into lengths of eleven inches by the shears; these are heated in an oven, and passed breadthways through case-hardened rolls: this is repeated till they are extended to twice the length of the intended plates: the pieces are then folded, and set on edge in the furnace till properly heated, when they are rolled double, the fold being put in first; they are thus extended to twice the length of the folded plate. Now two men, with strong tongs, tear the two leaves asunder at the fold, and fold each again separately, putting one into the other, like two sheets of paper; in this state they are heated, and rolled four thicknesses together, the next time eight, and so on, till the plate is reduced to the required thickness: in the very thinnest plate, such as is used for tagging laces, sixteen leaves are rolled together. In folding the plates, care is taken every time to put a new surface of metal outside, otherwise, those which were constantly reduced by the pressure of the adjacent leaves, would, at length, become grained on the surface; but by continually gaining new surfaces, which are smoothed by the immediate contact of the rollers, those which are laid against them are also rendered smooth. A small quantity of oil is sprinkled between the leaves, when they are first put in, and instantly spreading over the whole surface, prevents any adhesion; the plates are dressed square by the shears every time before they are folded, to remove those parts which, by projecting over the edges of the other leaves, are not so much reduced.

After being finished, dressed square, and the surface scoured, the plates are rolled, singly, between a pair of polished case-hardened rolls, without being heated; they are therefore extended but little in size, though rendered much harder, and more stiff. *Tin-foil* is rolled much in the same manner as the plates for tinning, but of course without heating.

Rolling, or Shingling Iron by Rollers.—This is a modern invention in the manufacturing of bar-iron, the rollers being substituted for the forge hammer to work the metal, in the process of rendering it malleable. This method is only used in conjunction with the *puddling* process, that is, puddling, or converting, cast-iron into a malleable state, by decarbonating it in a reverberating furnace; in this process the metal becomes divided into grains the size of mustard seeds, with a very slight cohesion, and full of interstices between the grains; it therefore requires to be stamped, or hammered, at a welding heat, into a solid mass; but rolling will also answer the purpose.

This was first discovered by the late Mr. Wilkinson, who had, in his extensive works at Broseley, in Shropshire, a pair of enormous rollers, moved by the beam of the steam-engine, not with a rotatory, but with a reciprocating motion; they were five feet diameter, near ten feet long, and weighed almost five tons each, although cast hollow, like garden rollers; sectors were fixed on the ends of the gudgeons, to turn each other, as they did not make above one-third of a revolution, and then moved back again. The circumference

of the rolls were grooved with grooves, gradually diminishing from one end to the other, in the same manner as the rollers shewn in *Plate V. fig. 1.* The mass of iron to be rolled was collected into a ball in the furnace, which was taken out, and passed through the greatest of the grooves. When it came through, a workman at the opposite side removed the ball to the next smallest groove, and by the returning motion of the rollers, it was carried back again to the front: the front workman then returned it in another groove, and so on, passing successively through the different grooves, until, by gradual consolidation, it was reduced to an imperfect bar of malleable iron. A number of these, being cut into lengths, were made up into faggots, or piles, and by a pair of rotatory rollers finished into bars. Mr. Wilkinson had a patent for this machine, but it was afterwards found that other rollers would effect the purpose better. In *fig. 1. of Plate V.* is a view of a pair taken from Mr. Samuel Smith's works, at Sheffield, Yorkshire, a gentleman who, we believe, was the first who brought them into use; the two grooves *e* and *f* are very coarse, and have teeth, that they may, more certainly, draw in the balls. The two next grooves are plain but concave, and the remainder are angular, to form square bars when the ball becomes consolidated. The use of these rollers is very similar to those we have just described, the ball of metal being taken from the furnace, and presented to the rolls. As soon as the metal comes through the rollers, a workman behind lifts it over the upper roll to the first workman, who puts it between them again: in this manner the metal is rolled ten or twelve times, being put through a smaller groove of the rollers at each time, so as to compress it in a greater degree every time, till at last it is reduced to a tolerable square bar; but the last groove *E, fig. 2,* has teeth in different parts of the groove, and at such distances from each other, that they will indent so deeply upon the angles of the bars, at every eight or ten inches of their length, as to render it easy to break them into short pieces when they come through. The pieces, thus formed, are piled four together, and put into a ball furnace, and, when heated, they are rolled into bars, by rollers shewn at *fig. 4,* which, at the first five grooves, *e, f,* are similar to the former, but the succeeding grooves, *h, k,* are made to receive the rings of the opposite roll, leaving small rectangular spaces, as is shewn by the light parts, *fig. 4,* through which the iron, being passed, is reduced to a parallel smooth bar. The successive grooves through which it is passed are each made narrower than the preceding, so as to reduce the bars to the width and thickness intended, in which state they are sent to market, or if required for the nail rods, or hoops, are cut up by the slitters. The rollers are thought to inclose the impurities in the iron, rather than expel them; but as rollers require much less power to give them motion than the hammer, it becomes worth the consideration of manufacturers to improve their construction, and render them equal in effect to the hammer. At present the rolled iron is not always so good in quality as the hammered, though this circumstance should not deter manufacturers from using it, as it is scarcely possible that a newly invented process should be at first brought to equal perfection with another which has exercised the ingenuity of manufacturers for ages past. But in the course of practice many improvements may arise, which will remain undiscovered if the process, in its present state, is neglected; even in this state the puddled iron, made with rollers, is by no means to be despised, when its price and quality are compared; it is for iron requiring the fibrous texture that this process is best adapted.

Rolling and slitting iron for nail rods or small hoops. The

iron which is subjected to this process is brought to the mill, *Plate IV.* before described, from the forge hammer, in bars of a size proportionate to the nail rod it is intended to make; these are cut into lengths by the shears, and heated in the furnace, then rolled repeatedly through the rollers, C, D, which are reduced every time it passes, until the bar becomes of the thickness for the square of the intended rod, half an inch for instance, and two, or two and a half, inches wide: it is, in this state, presented to the slitters E, F, and one end being introduced between the guide-bars of the slitters, is drawn in between them by the motion, and, by this means the ring of one roller presses a corresponding breadth of the hot metal into the space between the rings of the other roller; this being performed by both rollers, completely divides the bar into several rods of the same breadth with the rings of the rollers. A small leaden pipe is fixed over the cutters, and being perforated with holes, constantly lets fall a supply of cold water on the rollers, to prevent their becoming hot, and thus losing their hardness, which alone preserves their circular figure under the intense pressure they have to sustain in dividing the iron. The guide-bars are intended to force the iron rods, when cut, out of the grooves between the rings of the collar, which they would not otherwise quit, after being so forcibly pressed into them by the rings of the opposite roller. For making small hoops, the rods, as soon as they are formed, are put through the plain rolls again, and flattened into a hoop.

Rolling of Iron Hoops.—In the country these are made from iron bars, which are reduced in rollers, similar to *fig. 4*, to a size proper to produce the hoops required; these are cut into lengths, heated, and passed through the slitters, which divide them into three or four rods, which are immediately presented to the case-hardened rolls, and flattened out into a proper hoop. The mill shewn in *Plate IV.* is equally adapted for this work as for nail-rod; but for hoops, the addition of a proper fly-wheel would be an improvement, as the work is so much heavier.

In London, where a vast quantity of old hoops is to be procured, they are re-manufactured, and make the very best sort. The victualling-board alone consume many hundred tons annually for the service of the navy: the old hoops are made up into faggots, and shingled, or welded into bloom at one heat, by a forge-hammer, or in small works by rollers like *Plate V. fig. 1.* The blooms, being again heated, are rolled out into bars by the bar rollers, *fig. 4*, and these are cut into two or three lengths, according to the sizes of the intended hoops; these pieces are heated a third time, slit into rods as above described, and then formed into hoops by the case-hardened rolls. By successive improvements it has been found, that two heats are sufficient, the first for shingling and forming the bars, and the second for slitting and

flattening the hoops; but in either method the grand object is by faggoting and rolling, always in the direction of the length, to gain a fibrous texture to the iron.

Old hoops have been lately made up into new at one operation; by employing a greater power and velocity, and making up a smaller quantity at once, it may be effected at a single heat, instead of two or three. For this purpose the old hoops are cut into short lengths and faggoted in piles, the rivets being first cut out and the pieces straightened, that the piles may be more close and compact: these piles are heated in the usual kind of furnace to a good welding heat, and are rolled between the shingling rollers, being passed through two or three grooves till they are properly reduced to go through the flat-grooved bar rollers: after rolling through the three grooves thereof, they are put through the flat parts, and a guide is used to direct them straight forwards, without care or attention from the workman. The bar is then carried to the cutters, and slit into two or more rods, which are immediately and successively passed between a pair of plain, case-hardened rolls, to finish the hoops.

Vat-hoops, or others above two inches in width, do not require to be slit, but are at once carried from the bar rollers to the plain rollers, which finish them. The piles for shingling must not be made too large, or the hoops will not retain sufficient heat to be found; about 42lbs. will be a proper quantity. The mill for this manufacture must of course have great power, and the rollers should move with a sufficient velocity to enable the iron to be got through the whole process whilst sufficiently hot. The bar and shingling rollers should be placed close together in a line, and must make about 90 revolutions *per* minute; the case-hardened rollers should make 140 *per* minute, and should be placed in such relative situations as will be most convenient to convey the iron in the quickest manner from one pair to the next. A patent has been taken out by some, who pretend to the invention of the above method; but they cannot prevent other manufacturers using it, as it is no new invention, confining only in taking more care, and using rollers with a greater velocity.

The rolling-mill is not confined to the laminating of iron, but is likewise employed very extensively for reducing brass, copper, tin, lead, as well as gold and silver, into plates and bars. The latter metals are scarcely ever reduced by any other means than rolling; as this method makes no waste, is the most expeditious, and produces better work than hammering, or any other method, particularly when an equality of thickness and an even surface are desired; such, for example, as gold or silver, which is always to receive a polish; in these cases the rollers are made of steel hardened and polished on the surface with the most scrupulous nicety, that they may produce a perfect surface on the matters which have been passed through them.

Rope

ROPE, an assemblage of several twists or strings of hemp, twisted together by means of a wheel ; of various uses, as in binding, staving, drawing, suspending, &c. ; or, all cordage, in general, above one inch in circumference, mostly made of hemp spun into yarns or threads of a certain length ;

and a number of these yarns or threads, according to the size of the rope, are twisted together, and called a strand. Three of these strands twisted or laid together, is called a hawser-laid rope, and nine of them a cable-laid rope. See *ROPE-Making*.

When the rope is made very thick, it is called a *cable*; and when very small, a *cord*.

Though it be difficult to give a certain account of the forces required to bend ropes of different diameters, in making them go round bodies of different bignesses, yet to make no allowance for the loss of motion sustained thereby, would be as prejudicial to the practice of mechanics, as it would be to overlook the friction of the parts of engines. The difficulty of ascertaining this force arises from the different materials of which they are made, their different stiffness according as they are more or less twisted; and sometimes from the temperature of the air, as to moisture and dryness.

Dr. Defaguliers has computed the forces required to bend ropes of different diameters, stretched by different weights, round rollers of different bignesses. The result of his experiment is expressed in the following table.

Diameters of the ropes of three strands, expressed in tenth parts of an inch.	Weights stretching the ropes, expressed in lb. avoirdupois.	Resistance about a roller of half an inch diameter, in oz. avoirdupois.	Resistance about a roller of one inch diameter, in oz. avoirdupois.	Resistance about a roller of one and a half inch diameter, in oz. avoirdupois.
0.5	60	225	112½	75
0.2	60	90	45	30
0.1	60	45	22½	15
0.5	40	150	75	50
0.2	40	60	30	20
0.1	40	30	15	10
0.5	20	75	37½	25
0.2	20	30	15	10
0.1	20	15	7½	*

On the whole, it has been found by experiments, that the difficulty of bending a rope round a roller decreases directly as the diameter of the roller increases, or is, inversely, as the diameter of the roller. See Defaguliers, *Experim. Phil.* vol. i. p. 233, &c. See also *CORDAGE*.

A TABLE, shewing how many fathoms, feet, and inches of a rope of any size, under fourteen inches, makes a hundred weight, with the use of the table.

Inches.	Fathoms.	Feet.	Inches.	Fathoms.	Feet.	Inches.	Fathoms.	Feet.	Inches.	Fathoms.	Feet.	Inches.
1	486	0 0	4	24	0 0	8	7	3 6	11	3	4 1	14
1½	313	13 0	4½	21	3 0	8½	7	0 8	11½	3	3 3	14½
1¾	216	0 0	5	19	3 0	8¾	6	4 3	12	3	2 3	15
2	159	3 0	5½	17	4 0	9	6	2 1	12½	3	2 1	15½
2½	124	3 0	5¾	16	1 0	9½	6	0 0	12¾	3	2 0	16
2¾	96	2 0	6	14	4 6	9¾	5	4 0	13	2	7 8	16½
3	77	3 0	6½	13	3 0	10	5	2 0	13½	2	5 3	17
3½	65	4 0	6¾	12	2 0	10½	5	0 6	13¾	2	4 9	17½
3¾	54	0 0	7	11	3 0	10¾	4	5 0	14	2	4 0	18
4	45	5 2	7½	10	4 0	11	4	4 1	14½	2	3 6	18½
4½	39	3 0	7¾	9	5 6	11½	4	2 2	15	2	2 1	19
4¾	34	3 9	8	9	1 6	11¾	4	1 8				
5	30	1 6	8½	8	4 0	12	4	0 3				
5½	26	5 3	8¾	8	3 6	12½	3	5 7				

Suppose I want to know how much of eight-inch and quarter rope will make a hundred weight? Find 8¼ under inches, and against it, in the sixth column, you find 7 0 8, which shews in a rope of 8¼, there will be seven fathoms eight inches required to make one hundred weight.

A TABLE, shewing the weight of any cable or rope of 120 fathoms in length, and for every half inch from three inches to twenty-four in circumference.

Inches.	Cts.	Qrs.	Inches.	Cts.	Qrs.	Inches.	Cts.	Qrs.	Inches.	Cts.	Qrs.
3	2 1	7½	14	0	12	36	0	16½	68	0	21
3½	4 0	8	16	0	12½	39	0	17	72	1	21½
4	4 1	8½	18	0	13	42	1	17½	76	2	22
4½	5 0	9	20	1	13½	45	7	18	81	0	22½
5	5 1	9½	22	2	14	49	0	18½	85	2	23
5½	7 0	10	25	0	14½	52	2	19	90	1	23½
6	9 0	10½	27	2	15	56	1	19½	95	0	24
6½	10 2	11	30	1	15½	60	0	20	100	0	
7	10 1	11½	33	0	16	64	0	20½	105	0	

The greatest consumption of rope is used for the purposes of navigation in rigging of ships: where, though ropes include the whole cordage, there are several particularly denominated, and which have particular names given to them; as follow. 1. Awning-ropes are the ridge and side-ropes. The ridge-rope reeves through the trucks seized along the middle of the awning; the side-ropes reeve through the trucks seized along the side of the awning. By these ropes the awnings are spread between the masts. 2. Bell-rope, nine or ten feet in length, which splices round a thimble in the eye of the bell-crank. In the middle of the rope is a diamond-knot, and at the end a double wall-knot crowned. 3. Boat-rope, or panter, that by which the boat is towed at the stern; it splices with a thimble to a ring-bolt inside the stem. 4. Bolt-rope, the rope sewed to the edges of the sails, as the head-rope, foot-rope, and leech-rope. 5. Breast-rope, that fastened along the laniard of the shrouds, for safety, when heaving the lead in the chains. 6. Bucket-rope, that which is fastened to the bucket for hauling up water. 7. Buoy-rope, the one fastened to the buoy and crown of the anchor. 8. Davit-rope, the lashing which secures the davit to the shrouds when out of use. 9. Entering-ropes have their upper end thrust through the eye in the iron-stantions at the gangways, and are walled and crowned; and diamond-knots are made at every nine inches asunder in the whole length. 10. Grapnel-rope, that which is bent to the grapnel, by which the boats ride. 11. Guilt-rope, that fastened to an eye-bolt in the ship's side, and to the outer end of a boom projecting from the ship's side, by guys, to keep the boats clear from rubbing against the sides. 12. Heel-rope, that which hauls out the bowsprit of cutters, and the jib and studding-sail boom. 13. Man-ropes are for the security of the men going out upon the bowsprit. 14. Parral-ropes are to connect the ribs and trucks of the parral together. 15. Passing-ropes lead round the ship through the eyes in the quarter wait and fore-castle-stantions, have one end stopped through the eye of the gangway-stantion, with a wall-knot crowned, and are set forward through an eye-bolt in the knight-head with a laniard, having a thimble turned into the end. 16. Ring-ropes are occasionally made fast to the ring or stopper-bolts in the deck, and by crofs turns round the cable, to confine it more securely in stormy weather. 17. Slip-rope is to trice the bight of the cable into the

heads; a slip-rope is also used in casting off a vessel, till got into the tide's way, &c. 18. Swab-rope is made fast to the eye of the swab, to raise it out of the water. 19. Tiller-ropes are the ropes by which the tiller is worked by means of the steering-wheel. 20. Top-rope is the rope that is reeved through the sheave-hole in the heel of the topmast, to raise it by its tackle to the mast-head. 21. Yard-ropes are only temporarily used to heave the yards on board.

Ropes are distinguished by being either *cable-laid* or *hawser-laid*: the former are composed of nine strands, viz. three great strands, each of which is composed of three smaller strands, and each containing an equal number of threads: and a rope, cable-laid, eight inches in circumference, has 333 threads, equally divided, and laid into nine strands: the latter is made with three strands, each of which contains a certain number of rope-yarns, in proportion to the size of the rope required. A rope hawser-laid, eight inches in circumference, has 414 threads, equally divided, and laid into three strands. Thirty fathoms of yarn make eighteen fathoms of rope cable-laid, and so in proportion. Thirty fathoms of yarn make twenty fathoms of rope hawser-laid, and so in proportion. Ropes of from one to two and a half inches in circumference are hawser-laid; of three inches to ten inches, either hawser-laid or cable-laid; and from ten inches to any greater dimension, always cable-laid.

Twice-laid cordage is made of cat rigging, as shrouds, stays, mooring and other cables, which, if not much worn, will make good ropes for netting ships' sides, worming and wooding for cables, spun-yarn for seizing, worming for large stays, seizing for stops of blocks, small cable-laid ropes for warping ships, ratlines, scaffolding-ropes for dock yards, &c.

When the yarn of this old stuff is overhauled, a little thin tar should be poured on it, which will make it pliable and lie better. The yarn unfit for knotting will pick into oakum for caulking.

To open a cable, for making it into small ropes, hang the strands upon three hooks in the tackle-board, stretch it out tight upon the hooks in the sledge, and heave till they are untwisted; then draw out the yarn.

The process of making small ropes is similar to making large ones, except the twisting and closing, which are done by a back-frame wheel or a table-wheel. See the next article.

ROPE-MAKING, the art of preparing hemp, and spinning it into yarns or threads, and twisting those threads into strands, and laying those strands into cordage of the largest size, as the smallest kind is called *cord* or *twine* spinning.

Before we proceed further, it may be necessary to inform our readers of the different sorts of hemp proper to be made use of in the manufacturing of cordage. Of all the hems yet produced at our English markets, the Russian hemp has proved to be the best; it is grown in the southernmost parts of Russia, and shipped for England from the ports of St. Petersburg and Riga. The best sort is Riga rhine hemp: the next in quality is termed Petersburg clean hemp. These two are considered the best sorts of hemp to be used in making the strongest cordage.

The first process in the art of rope-making is, *Hatchelling the Hemp*.

Hatchelling the hemp, is the combing or clearing the ends, which else, in spinning, would run in with the long hemp, and so preparing it ready for the spinner; in the process of which, care and particular attention must be paid by the hatchellers that they do not use too great a quantity of oil, as in such case it will prevent the yarn from imbibing

its proper proportion of tar, and thereby prove a serious injury.

N. B. A small quantity of train-oil, say one pint to every hundred weight, sprinkled or daubed with a wad on the hemp, facilitates the hatcheller's business exceedingly, and is very necessary when the hemp is somewhat too dry, as the spinners are better able to perform their business when it has received such assistance.

The second and principal process to be attended to in the manufacturing of cordage, is *Spinning the Yarn*.

In spinning, particular attention must be paid by the spinner that the yarn be spun even, solid, and round; to accomplish which, he must spin with a strong even grip of the hand, taking care not to make his yarn larger in one place than in another, nor make a practice of spinning too much in a hurry; and the spinning-wheel must be kept turning a constant regular pace, otherwise the yarn so spun will lose its principal support, which is its proper turn, or twist, and will be little stronger than a parcel of straight hemp laid together, which would break in warping or straining up. The following regulations must be attended to in spinning. Every spinner is to spin out of the best hemp six threads, one hundred and sixty fathoms long, for a quarter of a day's work; but he is to spin out of the hemp which compose the bands by which the bales of hemp are bound together, no more than four threads, one hundred and sixty fathoms long, for one quarter of a day's work. To every twelve spinners there are allowed two hatchellers, one wheel-turner, and one wheel-tender: the wheel-tender's business is to splice the threads, and wind them on winches. The latter mentioned persons are paid in the same proportions as the spinners, that is, according to what work is done upon the wheel, only with this difference, the spinners are paid seven-pence per quarter for their work, the hatchellers, wheel-turner, and wheel-tender, only sixpence.

Each thread of the under-mentioned sizes of yarn to the spinning mark, (viz. 160 fathoms,) should weigh as follows:

	lbs.	oz.	drs.		lbs.	oz.	drs.
16	4	0	0	21	3	0	4
17	3	12	4	22	2	14	9
18	3	8	14	23	2	12	8
19	3	5	14	24	2	10	10
20	3	3	3	25	2	8	15

The third process to be attended to in the manufacturing of cordage, is *Warping the Yarn*.

Warping the yarn, is the stretching the yarns, previously to their being tarred, all to one given length, which, in full length rope grounds, is two hundred fathoms, and putting a slight turn or twist into it. The usual method is to warp the yarn either in whole or half haws, which is done by putting the number of threads you mean to draw down at once in a bite, into a block with one sheave, (the one end of the bite of yarn being fast at the upper end,) which being drawn down and fixed over the end of a hook made fast to a post at one hundred fathoms distance from the warping post, forms, when opened, a length of two hundred fathoms, as above-mentioned. The number of half bites, or blocks of yarn, contained in a whole or half hawl, is to be governed, in a great measure, by the size of the yarn to be warped,—as, for instance, 16 to 19-thread yarn is warped three hundred and thirty-six threads in a hawl, 20 to 25-thread yarn is warped four hundred threads in a hawl. In winding the yarns on the winches after they are spun, it is most usual to wind them on in companies of four in a company; but as that method can-

not always be pursued, it frequently happens that whole or half hawls of yarn are obliged to be warped in half bites of an odd number.

The following rules and regulations respecting the warping of yarn must be particularly attended to.

In a hawl of yarn containing three hundred and thirty-six threads, there should be warped as under-mentioned.

$\frac{1}{2}$ Bites.	Threads.	of	9 threads in a $\frac{1}{2}$ bite.
37	3		10 ditto.
33	6		11 ditto.
30	6		12 ditto.
28	0		13 ditto.
25	11		14 ditto.
24	0		15 ditto.
22	6		16 ditto.
21	0		17 ditto.
19	13		18 ditto.
18	12		19 ditto.
17	13		20 ditto.
16	16		

In a hawl of yarn containing four hundred threads, there should be warped as under-mentioned.

$\frac{1}{2}$ Bites.	Threads.	of	9 threads in a $\frac{1}{2}$ bite
44	4		10 ditto.
40	0		11 ditto.
36	4		12 ditto.
33	9		13 ditto.
30	11		14 ditto.
28	8		15 ditto.
26	10		16 ditto.
25	0		17 ditto.
23	9		18 ditto.
22	4		19 ditto.
21	1		20 ditto.
20	0		

When the yarn is warped in half hawls, it is to be carefully observed that only half the number of yarns, or threads, above-mentioned, are to be warped, and care should be taken to warp the number of threads as near as possible.

It requires three men to warp a hawl of yarn, who are employed as follows: viz. two men to warp (or draw the yarns to their proper distance), and one man to set up (that is, to tighten the yarns, and bring each yarn to its proper bearing): each man is allowed twelve threads (or two quarters of a day's work) for his labour.

To take the hawl of yarn up after it is warped, and carry the same into the tar-house, requires ten men, who are each paid one thread (viz. one penny) for their labour.

The fourth process to be attended to in the manufacturing of cordage, is *Tarring the Yarn*.

Tarring the yarn is a process which should be particularly attended to, being extremely careful that the tar is not boiling too fast nor too slow; if too fast, the tar will not stay in the yarn, if not hot enough, the tar will not sufficiently penetrate the yarn; therefore a strict medium must be carefully observed by the kettle-beater, as well as to keep the horse, or men, which turn the capstan round, going at a gentle, steady pace, thereby giving the yarn a proper time to imbibe its necessary proportion of tar, but at the same time not suffering it to be kept in the boiling tar too long, which is apt to make the yarn very tender, therefore should be very carefully avoided; and should the capstan be stopped by accident, the stop that keeps the yarn down must be instantly raised, and the yarn taken out. Particular attention

should also be paid in paying (or coiling) the yarn into the kettle, that too long a length be not payed in at once; if it is so done, the yarn will, of course, touch the bottom of the kettle, which it should, by no means, be suffered to do, as in such case it will imbibe the dregs and settlements of the tar appertaining to the bottom of the kettle, and make the yarn in such places black, or very much discoloured, and have a very unpleasing appearance in the rope when made. Yarn for cables requires more tar than for hawser-laid ropes. For standing and running rigging the less tar the better, provided the thread is well covered. It should be always remembered that the yarn, when tarred, should be overset (or removed) the same day, as this piece of business, being omitted, will be likely to prove of a serious consequence in heating and tendering the yarn, which at all times must be carefully avoided. In oversetting the yarn it should always be remembered that the yarn be well shook and opened for two or three days, as in so doing it admits the air, separates and hardens the yarns, and contributes very much to the strength of the cordage. The hawls or half hawls of yarn, when tarred, should always be weighed and tallied.

Tarring yarn requires three men, who are employed as follows: viz. one to heat the kettle, one to pay (or coil) the yarn in the kettle, and one to haul off and overset the yarn. They are, in general, paid in proportion to the work the spinners perform, which is called going by the wheel.

The fifth and last process to be attended to, is *Laying the Cordage*.

In laying cables, and all sorts of ropes in general, the great art lies in making each yarn to bear alike. For this purpose it was, particularly in the larger sized cables, that the patent machines have been introduced. Particular attention must be paid to this point, as therein consists the grand principle of making a strong rope. For all sorts of ropes which are to be immersed in the water, the utmost care must be taken to give the strands their proper hardness in their first process, according to the remarks laid down before, which will prevent the water from penetrating the strands, and thereby preserve the inside yarns of the cable; as, if this process is not regularly attended to, the inside yarns will be always wet, and very soon decay. It frequently happens that when the yarn is tarred somewhat too deep, that many a cable is spoiled, though not intentionally; the fear in the person who has the direction in making the cable, of turning a very dark coloured rope out of hand, prevents the regular make being given the cordage, as in pressing the yarn to their proper hardness, the tar will spring out, very much discolour the rope, and thereby give it a very unpleasing appearance, especially when the sun is shining very hot upon the yarn; to prevent which, in a great measure, care should be taken, in the summer months, to lay cables, and all sorts of cordage in general, either early in the morning, before the sun has much power on the yarn, which is also apt to tender it, or late in the evening, after the sun has set, or gone off the ground, or in heavy weather (by no means rainy); in which case your cordage will have a bright pleasing appearance, as the small fibres of the hemp will all yield to the top, and lay smooth, which otherwise would look rough, and appear as if the cordage was made of inferior hemp, though in fact it was not so, as all sorts of hemp have small fibres appertaining to them, and which it is past the art of man to prevent the sun from drawing up, and thereby making the rope look rough and unseemly.

N. B. The above remarks respecting taking advantage of the time for laying the cordage are only to be observed in uncovered grounds.

In *laying cordage*, the yarn for twirling into strands is hung on the hooks in the tackle-board, at the upper end of the ground, and upon hooks in the breast-board of the sledge, at the lower end, which are turned by men at both ends until the strands are hard; and are kept up from the ground by the stake-heads.

Before the turn is put in, the yarn should be stretched to its full extent by means of the tackle fixed from the sledge to the capstern, at twenty yards asunder, at the lower end of the ground; and when stretched to two hundred fathoms, the press is put upon the sledge and drag, before the tackle-fall is cast off; for if the yarn be not properly stretched before the tackle-fall is cast off, the rope will not be of its size, nor well made.

The strands should have a good hardening before the top is put in to lay the rope, and the layer should see that the heavers at the upper end keep the same hardness that the strands had before the top set off, nor should he begin to lay the rope until the sledge or wheel is moved by the power of the twist from the upper end.

When twisted sufficiently hard, the strands are hung on one hook in the breast-board of the sledge, but remain separate on the three hooks at the other end. The top is placed in at the sledge, and the rope twisted by turning the hooks at both ends one way, and, as the rope closes, the top moves towards the upper end.

When the top is put in, some of the weight should be taken off the sledge or drag, for if laid with as much weight as is used in the hardening, it would be too stiff, but, by removing a part of the weight, the strands will couch better.

The strength of the men at the hooks being greatly inadequate to the force required for twisting of cables, woolders are used, according to the size of the cable, at equal distances along the whole length.

Cables should be rounded by the lower hook after they are laid, to throw the turn well up. They are generally thought to wear best when slack-laid; but some think when short-laid.

Cablets used for tow-lines or hawsers, require the strands to be laid shorter than cable-strands, but not so short-laid in closing; for being used in water, they would become stiff, hard, unhandy to coil away, and liable to break in cold weather.

In all cable-laid ropes, the proportion of the circumference is to the length of the strand in one round, as 11 is to 15; that is, if the circumference be 14½ inches, the length of the strand in one circumference is 19¾ inches. In all hawser-laid rope, the proportion is as 12 to 16; that is, if the circumference be 7 inches, the length of the strand in one circumference is near 9½.

The strength of ropes depends on the hardening or well manufacturing, and not on the bare strength of the hemp; for it strengthens through every stage; viz. when first spun into yarn it is little better than hemp extended; when

twisted into strands, it shortens and strengthens as above, and increases in the same manner when laid into rope.

Where the diameter and circumference of one rope to another is as two to one, that is, where one rope is twice as big as another, the square of the diameter is as four to one; which shews, that one rope has four times as much yarn in it as the other, and consequently is four times as strong, according to the different magnitudes.

Cable-laid ropes shorten as five to three, and hawser-laid ropes as three to two; consequently the length of the yarn and strength will be accordingly; that is, the strength will be in the yarn, after it is laid in the rope, as much as if the rope-maker, in spinning, had allowed the same quantity of hemp in two feet as he did in three feet, so that the strength communicated by the process is two-thirds.

A rope is the same size when laid as the yarns were before twisted; so that what the yarns are lessened by twisting it is made up by shortening; from which it is inferred, that the yarns are always of an equal bigness, since the hemp is the same at one time as at another, and not any way diminished.

Were the strands single, without being twisted one about another, the strength would then be only in proportion as the area of each particular strand is in itself; but if the strands could possibly be twisted so as to be directly perpendicular to the base, the strength would then be found, by multiplying the diameter of the strands and the diameter of the whole rope one into the other, and the half of the product would be the strength of the said strands; but more particularly take the area of the single strand and area of the whole cable, and add them together, and the half of that will shew the strength of each strand when they are well twisted together.

But as it may be observed the strands lie at a certain angle between a perpendicular and the base, so that, as the angle of incidence is to radius, so is the relative to the absolute strength.

Respecting the *Banding of Cordage*.—In the calculations specifying the weights of the different lengths of cordage, such weights are to be considered as the neat weights of the rope without bandage.

N. B. To every hundred weight of cordage the manufacturer is allowed to put on four pounds weight of bands; those bands are composed of the shakings, flyings, and strings with which the hemp is tied together, formed into an inferior kind of cordage; but it is to be observed those are all weighed to the rope-makers as good hemp, and paid for accordingly, therefore if he was not allowed to apply the refuse to such purpose, he must either put a higher price on his cordage, or be a very considerable loser. At the same time it should be considered, that as it is necessary that every coil of rope should be bound together for the convenience of carriage, stowage, &c. this kind of bandage answers such purpose in every degree, as well as if the coils were bound with bands made from the best hemp.

TABLE I.

These sizes of Yarn are warped 336 Threads, and from 19 are warped 400 Threads in a Hawl.

	16	17	18	19	20	21	22	23	24	25
A { Weight of one thread 200 fathoms long. }	lb. oz. dr.	lb. oz. dr.	lb. oz. dr.	lb. oz. dr.	lb. oz. dr.	lb. oz. dr.	lb. oz. dr.	lb. oz. dr.	lb. oz. dr.	lb. oz. dr.
	5 0 0	4 11 5	4 7 2	4 3 6	4 0 0	3 12 5	3 10 3	3 7 10	3 5 5	3 3 3
B { One-tarred thread 200 fathoms long should weigh from }	6 3 0 to 6 4 0	5 13 3 to 5 14 2	5 8 0 to 5 8 14	5 3 6 to 5 4 3	4 15 3 to 5 0 0	4 11 5 to 4 12 3	4 8 0 to 4 8 11	4 4 14 to 4 5 9	4 2 0 to 4 2 10	3 15 6 to 4 0 0
C { Ten fathoms of each size of B should weigh from }	0 4 15½ to 0 5 0	0 4 10½ to 0 4 11½	0 4 6½ to 0 4 6¾	0 4 2¾ to 0 4 3½	0 3 15½ to 0 4 0	0 3 12½ to 0 3 13	0 3 9½ to 0 3 10½	0 3 7 to 0 3 7½	0 3 4½ to 0 3 5½	0 3 2½ to 0 3 3½
D { Weight of each hawl before tarred. }	C. qr. lb.	C. qr. lb.	C. qr. lb.	C. qr. lb.	C. qr. lb.	C. qr. lb.	C. qr. lb.	C. qr. lb.	C. qr. lb.	C. qr. lb.
	15 0 0	14 0 13	13 1 9	12 2 14	14 0 4	13 2 11	12 3 13	12 1 19	11 3 17	11 1 20
E { Weight of each hawl when tarred from }	18 2 7 to 18 3 0	17 1 25 to 17 2 16	16 2 0 to 16 2 18	15 2 15 to 15 3 4	17 2 20 to 17 3 12	16 3 9 to 17 0 0	15 3 19 to 16 0 9	15 1 14 to 15 2 3	14 2 25 to 14 3 14	14 0 16 to 14 1 4

N.B. The calculations of B and C will be found extremely useful, provided the yarn be spun and tarred regular, as by weighing one single yarn, or even ten fathoms, the size of the yarn may be ascertained, without being at the trouble of weighing the hawls.

TABLE II.

Shewing the Number of Threads to work *per* Hook for three-strand cable-laid Cordage of 6, 12, 18, and 24 Inches in Circumference, of the undermentioned Sizes of Yarn, with the Girt of each Strand, and Weight of each Cable: also the Number of Men required to lay both Strands and Cable, with the Allowance to each Man for his Labour.

The N ^o of Threads here mentioned weigh 99 lb. to 100 lb.		Sizes of Yarn										Weight of each Cable 120 Fathoms long.	Men for Strands.	Threads <i>per</i> Strand.	Men for Cables.	Threads <i>per</i> Cable.
		16	17	18	19	20	21	22	23	24	25					
Sizes in Inches.	Girt of Strands.	Threads <i>per</i> Hook.														
6	3 ½	18	19	20	21	22	23	24	25	27	28	C. qr. lb. 9 0 0	7	6	15	6
12	6 ½	72	76	80	85	89	94	98	103	107	112	36 0 0	17	6	37	8
18	9 ½	162	171	181	191	201	211	221	231	242	252	81 0 0	31	8	73	12
24	12 ½	288	304	322	340	358	376	394	412	430	448	144 0 0	42	*10	108	18

* Six threads are called a quarter of a day's work, for which each workman is paid 7*d.*, and so on in proportion for a greater or less number.

Remarks and Directions how to apply Tables I. and II.

Example.—Suppose a cable of 12 inches in circumference is wanted to be made, the hawls of yarn out of which, upon examining the weights, are found to weigh 16 cwt. 2 qr. 10 lb. *per* hawl of 336 threads. A reference is to be made to Table I. line E, and the weight, being between 16 cwt. 2 qr. 0 lb. and 16 cwt. 2 qr. 18 lb. will be found to answer to 18-thread yarn. Then look down the 18-thread column, Table II., and upon the line of 12, (the size in the margin,) is found 80 threads *per* hook, which is the number of threads to be laid up *per* hook for the cable to be made of the weight *per* hawl of yarn of 336 threads above specified.

Again, if the hawls of yarn should be tarred of such a weight (say for example) requires to be worked between a

17 and an 18-thread yarn, in such case take the number of threads *per* hook to be worked for the size of the cable demanded, as should be worked both for 17 and 18-thread yarn; add them together, and take half the number of threads so added, to work *per* hook for the cable; but if there should happen in dividing to be an odd thread remaining, you must observe to which side the weight of your hawl of yarn is most inclining, and throw the thread in dispute to the heaviest side. The same rules must be observed in consulting all the following tables.

Remarks.—In laying three-strand cable-laid cordage, if you are in doubt respecting the size of your yarn, you must girt the yarn you purpose laying in one strand, and that should be half the size of your cable.

In hardening the strands in the laying of cable-laid

cordage, you must work with (in addition to your sledge) one prefs-barrel to every 20 threads contained in your strand; but in laying the strand, hardening, and laying the cable, you must have only one prefs-barrel to every 40 threads contained in your strand or cable. The above is to be considered as a standing rule in covered rope-grounds, but in open grounds, the prefs must be varied according to the state of

the bottom of the ground, which, after a shower of rain, or in damp weather, will be naturally soft, and occasion the sledge to draw exceedingly heavy, and of course want the less weight of prefs.

N. B. The weight of a prefs-barrel should be from $3\frac{1}{2}$ to 4 cwt.

TABLE III.

Shewing the different shrinking Proportions of the Yarns and Strands in each Process in making the undermentioned Lengths of Cable.

Length in fathoms of cable.	Length of yarns required to be warped.	In hardening the strands, the yarn will shrink 1-5th part of the whole length warped, and is called the strand's hardening mark.	In laying the strands, the strand will shrink 1-10th part of the whole length warped, and is called the strand's going distance.	In hardening the cable-strands previous to laying the cable, the strands will shrink 1-30th part of the whole length warped, and is called the cable's hardening mark.	In laying the cable it will shrink 1-15th part of the whole length warped, which brings it to the length required.
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The Sledge should move up to the following Distances from the Tackle-Posts.

	fms.	fms.	ft.	fms.	ft.	fms.	ft.	fms.	ft.	in.	fms.
$\frac{1}{4}$ Cable	40	66	4	53	2	46	4	44	2	8	40
	60	100	0	80	0	70	0	66	4	0	60
	80	133	2	106	4	93	2	88	5	4	80
Whole	120	200	0	160	0	140	0	133	2	0	120

TABLE IV.

Shewing the Weights of three-strand cable-laid Cordage.

	fms.	3-Inch Cable.	6-Inch Cable.	9-Inch Cable.	12-Inch Cable.	15-Inch Cable.	18-Inch Cable.	21-Inch Cable.	24-Inch Cable.
		C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.
$\frac{1}{4}$ Cable	40	0 3 0 0	3 0 0 0	6 3 0 0	12 0 0 0	18 3 0 0	27 0 0 0	36 3 0 0	48 0 0 0
$\frac{1}{2}$	60	1 0 14 0	4 2 0 0	10 0 14 0	18 0 0 0	28 0 14 0	40 2 0 0	55 0 14 0	72 0 0 0
$\frac{3}{4}$	80	1 2 0 0	6 0 0 0	13 2 0 0	24 0 0 0	37 2 0 0	54 0 0 0	73 2 0 0	96 0 0 0
Whole	120	2 1 0 0	9 0 0 0	20 1 0 0	36 0 0 0	56 1 0 0	81 0 0 0	110 1 0 0	144 0 0 0

It is necessary to be understood, that in rope-making (according to the nature of the rope), weight will give size, and size will give weight, if properly made.

Rule.—To calculate very nearly the weight of any sized rope from 3 to 24 inches in circumference, 120 fathoms long, and lesser lengths in proportion; as may be readily proved by the above table, viz. multiply the size of the rope by itself, and one-fourth of that product is the weight of a hundred of 112 pounds.

Example.—Suppose the rope 12 inches in circumference; $12 \times 12 :: 144$, the fourth of which is 36 hundred weight, or 3732 pounds, the weight of 120 fathoms of rope 12 inches in circumference. Again, 40 fathoms is the third of 120 fathoms; and the third of 36 cwt. is 12 cwt. the weight of 40 fathoms of 12-inch cable, as above.

Directions how to apply the following Tables.

In which is considered the four most principal sorts of yarns made use of in cable-laid cordage, viz. 16, 18, 20, and 25-thread yarn, and in hawser-laid cordage, to the three principal sorts of yarn made use of, viz. 18, 20, and 25-thread yarn, as it is very seldom any other size yarn is made for either cable or hawser-laid rope, except very particularly ordered to the contrary. The particulars of every rope of the sizes mentioned in the tables are fully explained

to the length of twenty fathoms, which will be found quite a sufficient guide for a rope of any length required:

As for Example.—Suppose I want a taper cable-laid rope to be made out of 16-thread yarn, 60 fathoms long, and 6 inches in circumference, to be tapered $\frac{1}{3}$ ds the length, and $\frac{1}{3}$ ds the size of the rope. I refer to Table V., and find under the figure 6, (the size demanded,) that it must be worked 5 threads per hook in the shank, the length of yarn to be warped for which, for 20 fathoms (I find in the margin) requires to be 33 fathoms 2 feet, three times which is 100 fathoms, the length of yarn required to be warped for the shank of a rope of 60 fathoms long. I then observe, in the next column on the right in the margin, the length of yarn required in the head for 20 fathoms is 11 fathoms 0 feet 8 inches, three times which is 33 fathoms 2 feet, the length of yarn required in the head to the first taper for a rope of 60 fathoms. Next refer to the number of tapers to be worked, which, upon looking under the figure 6, (the size demanded,) I find to be 9, the distance between them I find (upon casting my eye down the column) to be 14 feet $7\frac{1}{2}$ inches for 20 fathoms, three times which is 44 feet $5\frac{1}{2}$ inches, the distance to be observed between the tapers for a rope of 60 fathoms, being the length demanded. The same rule is to be observed, either adding or multiplying, according as required in all the tables of a similar description.

TABLE V.

Shewing the Number of Threads to work per Hook, both in the Shaak and Tapers, in making three-strand taper cable-laid Cordage of the following Sizes, and the Lengths thereto prefixed, with the Lengths of Yarn required for the same, and the Distance to be observed between the Tapers; for 16, 18, 20, and 25-thread Yarn.

To Taper two-thirds the Length, and two-thirds the Size of the Rope

Fathoms demanded.	Lengths of Yarn in the Shaak or whole Parts.	Lengths of Yarn in the Head to the first Taper.	Lengths of Yarn to the Taper.	Distance between the Tapers.															
				ft. in.	fms. ft. in.	fms. ft. in.	fms. ft. in.	fms. ft. in.	fms. ft. in.	fms. ft. in.	fms. ft. in.	fms. ft. in.	fms. ft. in.	fms. ft. in.	fms. ft. in.	fms. ft. in.	fms. ft. in.		
5	8 2	2 4 8	5 3 4	8 4	6 8	5 6½	4 2	4 2	2 9½	2 4½	1 10½	1 7½	1 4½	1 1½	1 0½	1 0½			
10	16 4	5 3 4	11 0 8	16 8	13 4	11 1½	8 4	8 4	5 6½	5 6½	3 8½	3 2½	2 0½	2 2½	2 0½	2 0½			
15	25 0	8 2 0	16 4 0	25 0	20 0	16 8	12 6	10 0	7 8½	5 6½	5 6½	4 6½	3 0½	3 0½	3 0½	3 0½			
20	33 2	11 0 8	22 1 4	33 4	26 8	22 2½	16 8	13 4	10 3½	7 5½	7 4½	6 4½	5 1½	4 5½	4 5½	4 5½			
5	8 2	2 4 8	5 3 4	8 4	5 6½	4 9½	3 8½	4 2	2 6½	1 10½	1 8	1 4½	1 3½	1 1½	1 0½	1 0½			
10	16 4	5 3 4	11 0 8	16 8	11 1½	9 6½	7 4½	6 8	5 1½	3 8½	3 4	2 9½	2 6½	2 4½	2 2½	2 2½			
15	25 0	8 2 0	16 4 0	25 0	16 8	14 3½	11 1½	10 0	7 8½	5 6½	5 6½	4 6½	3 0½	3 0½	3 0½	3 0½			
20	33 2	11 0 8	22 1 4	33 4	22 2½	19 0½	14 9½	13 4	10 3½	7 5½	7 4½	6 4½	5 1½	4 5½	4 5½	4 5½			
5	8 2	2 4 8	5 3 4	6 8	5 6½	4 2	3 4	2 9½	2 4½	1 11½	1 8	1 6½	1 3½	1 1½	1 0½	1 0½			
10	16 4	5 3 4	11 0 8	13 4	11 1½	8 4	6 8	5 6½	4 9½	3 11½	3 4	2 9½	2 6½	2 4½	2 2½	2 2½			
15	25 0	8 2 0	16 4 0	20 0	16 8	12 6	10 0	8 4	7 1½	5 10½	5 0	4 6½	3 0½	3 0½	3 0½	3 0½			
20	33 2	11 0 8	22 1 4	26 8	22 2½	16 8	13 4	11 1½	9 6½	7 10½	6 8	5 1½	4 5½	4 5½	4 5½	4 5½			
5	8 2	2 4 8	5 3 4	5 6½	4 9½	3 4	2 9½	2 2½	1 10½	1 6½	1 4	1 2½	1 0½	0 9½	0 8½	0 8½			
10	16 4	5 3 4	11 0 8	11 1½	9 6½	6 8	5 6½	4 5½	3 8½	3 0½	2 8	2 4½	2 0½	1 7½	1 5½	1 4½			
15	25 0	8 2 0	16 4 0	16 8	14 3½	10 0	8 4	6 8	5 6½	4 6½	3 6½	3 0½	2 8½	2 4½	2 2½	2 0½			
20	33 2	11 0 8	22 1 4	22 2½	19 0½	13 4	11 1½	8 10½	7 5½	6 0½	4 9½	4 4	3 0½	2 7½	2 10½	2 8½			

TABLE VI.

Shewing the Number of Threads to work *per* Hook and Heart for cable-laid Stays, four Strands and a Heart, of 5, 10, 15, and 19 Inches in Circumference, of the undermentioned Sizes of Yarn, with the Girt of each Strand prefixed against each Size.

Number of Threads of under to weigh from 99 to 100lb.		16	17	18	19	20	21	22	23	24	25
Size in Inches.	Girt of each Strand.	Threads <i>per</i> Hook and Heart.									
5	2 $\frac{3}{8}$	9	9	10	11	11	12	12	13	13	14
10	4 $\frac{1}{2}$ $\frac{2}{5}$	35	37	39	41	43	46	48	50	52	55
15	6 $\frac{1}{2}$ $\frac{4}{5}$	79	84	89	94	99	104	109	114	119	124
19	8 $\frac{1}{2}$ $\frac{7}{8}$	127	135	143	151	159	167	175	183	191	199

The shrinking proportions of cable-laid stays are exactly the same as in three-strand cable-laid cordage, except in the closing the stay, which being composed of four strands, lie much closer in the rope than three strands, and having the heart of the stay to encompass, occasions the strands to shorten in a much greater proportion than in three-strand cable-laid cordage. The stay, in closing, will shorten $\frac{1}{4}$ parts of the length of yarn first warped.

TABLE VII.

Shewing the Weight of cable-laid Stays, four Strands and a Heart, from 5 to 19 Inches in Circumference, and from 5 to 30 Fathoms in Length.

Fathoms in Length.	5-Inch Stay.	7-Inch Stay.	9-Inch Stay.	11-Inch Stay.	13-Inch Stay.	15-Inch Stay.	17-Inch Stay.	19-Inch Stay.
	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.
5	0 1 3 9	0 2 4 5	0 3 16 10	1 1 9 11	1 3 17 2	2 2 2 3	3 0 25 9	4 0 7 10
10	0 2 7 2	1 0 8 10	1 3 5 4	2 2 19 6	3 3 6 4	5 0 4 6	6 1 23 2	8 0 15 4
15	0 3 10 11	1 2 12 15	2 2 21 14	4 0 1 1	5 2 23 6	7 2 6 9	9 2 20 11	12 0 22 14
20	1 0 14 4	2 0 17 4	3 2 10 8	5 1 10 12	7 2 12 8	10 0 8 12	12 3 18 4	16 1 2 8
25	1 1 17 13	2 2 21 9	4 1 27 2	6 2 20 7	9 2 1 10	12 2 10 15	16 0 15 13	20 1 10 2
30	1 2 21 6	3 0 25 14	5 1 15 12	8 0 2 2	11 1 18 12	15 0 13 2	19 1 13 6	24 1 17 12

TABLE VIII.

Shewing the Number of Threads to work *per* Hook for four-strand cable-laid Cordage without a Heart, from 5 to 24 Inches in Circumference, of the Sizes of Yarn undermentioned, with the Weight of each Cable prefixed.

No. of Threads weighing from 99 to 100lb.	16	17	18	19	20	21	22	23	24	25	Weight of each Cable 120 Fathoms long.
Size in Inches.	Threads <i>per</i> Hook.										C. qr. lb.
5	9	10	10	11	12	12	13	13	14	15	6 2 10
10	38	40	42	45	47	50	52	54	57	59	25 3 6
15	85	91	96	101	107	112	118	123	128	134	58 3 0
20	152	162	171	181	190	200	209	219	228	238	104 1 9
24	219	233	247	260	274	288	301	315	329	343	150 1 2

TABLE IX.

Shewing the Length of Yarn required to be warped, and the different shrinking Proportions in making the undermentioned Lengths of four-strand cable-laid Cordage.

Fathoms demanded.	Lengths of Yarn warped.			Strand's Hardening Mark.			Strand's Going Distance.			Cable's Hardening Mark.			Cable's Length.
	fms.	ft.	in.	fms.	ft.	in.	fms.	ft.	in.	fms.	ft.	in.	
10	17	0	6	13	4	0	11	5	9	11	2	4	10
20	34	1	0	27	2	0	23	5	6	22	4	8	20
40	68	2	0	54	4	0	47	5	0	45	3	4	40
60	102	3	0	82	0	0	71	4	6	68	2	0	60
80	136	4	0	109	2	0	95	4	0	91	0	8	80
120	205	0	0	164	0	0	143	3	0	136	4	0	120

N.B. The shrinking proportions of four-strand cable-laid cordage is exactly the same as three-strand, except in closing the cable, which consisting of four strands, lie much closer in the rope than three strands, but not having a heart to encompass it, does not diminish in length so much as cable-laid stays. The cable in closing will shorten $\frac{1}{12}$ parts of the length of yarn first warped.

It being rather unusual to lay cables with a greater number of strands than four, the above tables are not laid down for a greater proportion,—but to know how to find the number of threads to work *per* hook for a greater number may at some time be necessary, therefore the following method

must be pursued to lay a cable in as many strands as may be thought expedient. Suppose a five-strand cable-laid rope is wanted to be made, you first square the size of the rope proposed to be made, and multiply that product by the size yarn you mean to make your cable from, that product divide by 52, and the quotient will be the number of threads to work *per* hook for a five-strand cable-laid rope. If for a six-strand, proceed as before, and divide by 62; for a seven-strand, divide by 72; for an eight-strand, divide by 82; and so on, adding 10 to your divisor for every strand you mean to increase in number in your cable.

TABLE X.

Shewing the Prime Cost to the Manufacturer in each Process, in making the undermentioned Sizes of three-strand cable-laid Cordage, with the Weight of Hemp and Tar required for each Rope.

Size.	Hatchelling, Wheel-turning, and Tending.	Expence at 8d. per Quarter	Spinning.	Expence at 7d. per Quarter.	Warping, Taking-up, and Tarring, at 9s. per Hawl.	Laying at 7d. per Quarter.	Total Expence of Manufacturing into Cordage.	Weight of Hemp required for each Rope.	Weight of Tar required for each Rope.
In.	qr. thds.	L. s. d.	qr. thds.	L. s. d.	L. s. d.	L. s. d.	L. s. d.	C. qr. lb.	C. qr. lb.
5	7 3	0 3 9	22 3	0 13 1	0 2 10 $\frac{1}{2}$	0 15 5	1 15 1 $\frac{1}{2}$	5 0 0	1 1 0
10	31 1 $\frac{1}{2}$	0 15 7 $\frac{1}{2}$	93 4 $\frac{1}{2}$	2 14 7 $\frac{1}{2}$	0 12 1	2 6 1	6 8 5	20 0 0	5 0 0
15	70 3 $\frac{1}{2}$	1 15 3 $\frac{1}{2}$	211 5 $\frac{1}{2}$	6 3 6 $\frac{1}{2}$	1 7 3	5 17 10	15 3 11	45 0 0	11 1 0
20	125 0	3 2 6	375 0	10 18 9	2 8 2	11 18 0	28 7 5	80 0 0	20 0 0
24	180 0	4 10 0	540 0	15 15 0	3 9 5	15 11 6	39 5 11	115 0 23	28 3 5

The above table is calculated according to the usual mode of rope-making, and is termed by the trade working by the square, which is performed in the following manner: Suppose a cable 15 inches in circumference, the square of 15 is 225, the half of which is 112 $\frac{1}{2}$; that is, 113 threads *per* hook must be laid up for a 15-inch cable, proceeding in the same manner for any size demanded, which mode of working answers to

sixteen-thread yarn in all sizes of three-strand cable-laid cordage.

Where the diameter and circumference of one rope to another is as 2 to 1, that is, where one rope is twice as big as another, the square of the diameter is as 4 to 1, which shews that one rope has four times as much yarn in it as the other, and consequently is four times as strong, according to the different magnitudes.

TABLE XI.

Shewing the Number of Threads *per* Hook to work for three-strand hawser-laid Cordage, of 3, 6, 9, and 12 Inches in Circumference, of the Sizes of Yarn undermentioned, with the Weight of each Rope, and the Number of Men required to lay the same, with the Allowance to each Man for his Labour.

N ^o of Threads 99 to 100 lb. Weight.	16	17	18	19	20	21	22	23	24	25	Weight of each Rope 133.2 long.	Men for Rope.	Threads <i>per</i> Rope.
Size in Inches.	Threads <i>per</i> Hook.												
3	16	17	18	19	20	21	22	23	24	25	C. qr. lb.		
6	64	68	72	76	80	84	88	92	96	100	2 2 17	8 0	6
9	144	153	162	171	180	189	198	207	216	225	10 2 12	22 0	12
12	256	272	288	304	320	336	352	368	384	400	23 1 13	37 0	15
											42 1 20	45 0	15

Remarks.—In hardening the strands, and in laying hawser-laid cordage, it must be worked with (in addition to the weight of the sledge) one prefs-barrel for every twenty threads contained in the rope. This is to be considered as a standing rule in covered rope-grounds, but in open grounds the prefs must be varied according

to the state of the ground, as mentioned in cable-laid cordage.

In laying three-strand hawser-laid cordage, if there is any doubt respecting the size of the yarn, you must girt the yarn you propose laying in two of your readys (or strands), and that should be just the size of the rope.

TABLE XII.

Shewing the Length of Yarn required to be warped, and the different shrinking Proportions of the Yarn in each Process, in making the undermentioned Lengths of hawser-laid Rope, and also the Weight.

	Fathoms of Rope in Length.	Length of Yarn to be warped.	The Sledge should move to the following Marks from the Tackle-Poles.		4-Inch.	1½-Inch.	2-Inch.	4-Inch.	6-Inch.	8-Inch.	10-Inch.	12-Inch.
			Rope's Hardening Mark.	Rope's Length.	Weight.	Weight.	Weight.	Weight.	Weight.	Weight.	Weight.	Weight.
Half } Coil	fms. ft.	fms.	fms.	fms. ft.	qr. lb. oz.	qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.
	10 0	15	12	10 0	0 2 7½	0 4 15	0 0 9 14½	0 1 11 9½	0 3 5 1½	1 1 18 6½	2 0 23 8	3 0 20 6
	20 0	30	24	20 0	0 4 15	0 9 4	0 0 19 12½	0 2 23 3	1 2 10 3	2 3 8 12½	4 1 19 0	6 1 12 12
	40 0	60	48	40 0	0 9 14	0 19 12	0 1 11 9	1 1 19 6	3 0 20 6	5 2 17 9	8 3 10 0	12 2 25 8
	66 4	100	80	66 4	0 16 8	1 5 0	0 2 10 0	2 1 12 0	5 1 6 0	9 1 20 0	14 2 26 0	21 0 24 0
	80 0	120	96	80 0	0 19 12	1 11 8	0 2 23 2	2 3 8 12	6 1 12 12	11 1 7 2	17 2 30 0	25 1 23 0
Whole } Coil	100 0	150	120	100 0	0 24 11	1 21 6	0 3 14 14½	3 2 3 15	7 3 22 15	14 0 15 14½	22 0 11 0	31 3 7 12
	120 0	180	144	120 0	1 1 10	2 3 4	1 0 6 11	4 0 26 2	9 2 5 2	16 3 21 11	26 2 2 0	38 0 20 8
	133 2	200	160	133 2	1 5 0	2 10 0	1 0 20 0	4 2 24 0	10 2 12 0	18 3 12 0	29 1 24 4	42 1 20 0

Remarks.—In hardening the strands the yarn will shrink one-fifth of the whole length, which is called the rope's hardening mark.

In laying the rope the strands will shrink one-sixth of the remaining distance, which brings the rope to the length required.

TABLE XIII.

Shewing the exact Cost to the Manufacturer in each different Process as undermentioned, in making the following Sizes of three-strand hawser-laid Cordage, with the proper Proportions of Hemp and Tar necessary for each Rope.

Size in Inches.	Hatchel- ing, Wheel turning, and Tend- ing.	Expense at 6d. per Quarter.	Spinning.	Expense at 7d. per Quarter.	Warping, Taking-up, and Tarring Expense at 9s per Hawl.	Laying Ex- pence at 7d. per Quarter.	Total Expense of manufac- turing into Cordage.	Weight of Hemp re- quired for each Rope.	Weight of Tar required for each Rope.
	qr. thds.	L. s. d.	qr. thds.	L. s. d.	L. s. d.	L. s. d.	L. s. d.	C. qr. lb.	C. qr. lb.
2	1 4	0 0 10	5 0	0 2 11	0 0 7 $\frac{1}{2}$	0 1 9	0 6 1 $\frac{1}{2}$	0 3 22	0 0 26
4	6 4	0 3 4	20 0	0 11 8	0 2 7	0 7 0	1 4 7 $\frac{1}{2}$	3 3 23	0 3 21
6	15 0	0 7 6	45 0	1 6 3	0 5 8	1 5 8	3 5 1	8 1 27	2 0 13
8	26 4	0 13 4	80 0	2 6 8	0 10 3	1 15 0	5 5 3	15 0 10	3 3 2
10	41 4	1 0 10	125 0	3 12 11	0 16 1	3 5 7	8 15 5	23 2 10	5 3 14
12	60 0	1 10 0	180 0	5 5 0	1 3 2	3 5 7	11 3 9	33 3 22	8 1 26

The foregoing table is grounded (as termed by the trade) upon the principle of the square, but the method of working upon this principle differs between cable and hawser-laid cordage. The mode pursued for making hawser-laid cordage is as follows: Suppose it is wanted to make a three-strand hawser-laid rope, six inches in circumference; the

square of 6 is 36, and twice 36 is 72, which is the number of threads to work *per* hook for a six-inch three-strand hawser-laid rope. The same method must be pursued, according to this way of working, for any other size, and answers to eighteen-thread yarn in all three-strand hawser-laid cordage. See Table XI.

TABLE XIV.

Shewing the Weight of Yarn (of the four most general Sorts made use of) capable of being spun by each of the following Number of Spinners, at eight Quarters, (or 48 Threads) *per* day, in 1 Day, 1 Week of 6 Days, 1 Month of 24 Days, and 1 Year of 13 Months; with the Yield of Cordage at the Year's End prefixed against each Number of Spinner's Work.

Numb. of Spinners for	Weight of Yarn per Day.	Weight of Yarn per Week.	Weight of Yarn per Month.	Weight of Yarn per Year.	Yield of Cordage.
	Cwt. qrs. lbs.	Cwt. qrs. lbs.	Tons. cwt. qrs. lbs.	Tons. cwt. qrs. lbs.	Tons. cwt. qrs. lbs.
16-thread Yarn.					
2	3 1 20	20 2 8	4 2 1 4	53 9 2 24	66 17 0 16
4	6 3 12	41 0 16	8 4 2 8	106 19 1 20	133 14 1 4
6	10 1 4	61 2 24	12 6 3 12	160 9 0 16	200 11 1 20
8	13 2 24	82 1 4	16 9 0 16	213 18 3 12	267 8 2 8
10	17 0 16	102 3 12	20 11 1 20	267 8 3 8	334 5 2 24
12	20 2 8	123 1 20	24 13 2 24	320 18 1 4	401 2 3 12
18-thread Yarn.					
2	3 0 0	18 0 0	3 12 0 0	46 16 0 0	58 10 0 0
4	6 0 0	36 0 0	7 4 0 0	93 12 0 0	117 0 0 0
6	9 0 0	54 0 0	10 16 0 0	140 8 0 0	175 10 0 0
8	12 0 0	72 0 0	14 8 0 0	187 4 0 0	231 0 0 0
10	15 0 0	90 0 0	18 0 0 0	234 0 0 0	291 10 0 0
12	17 0 0	108 0 0	21 12 0 0	280 16 0 0	351 0 0 0
20-thread Yarn.					
2	2 3 4	16 2 24	3 3 3 12	43 9 0 16	55 2 1 20
4	5 2 8	33 1 20	6 7 2 24	86 18 1 4	111 0 3 12
6	8 1 12	50 0 16	9 11 2 8	130 7 1 20	166 3 1 4
8	11 0 16	66 3 12	12 15 1 20	173 16 2 8	222 1 2 24
10	13 3 20	83 2 8	15 19 1 4	217 5 2 24	277 4 0 16
12	16 2 24	100 1 4	19 3 0 16	260 14 3 12	332 6 2 8
25-thread Yarn.					
2	2 0 22	13 0 20	2 12 2 24	34 5 1 4	42 16 2 12
4	4 1 16	26 1 12	5 5 1 20	68 10 2 8	85 13 0 24
6	6 2 10	39 2 4	7 18 0 16	102 15 3 12	129 9 3 8
8	8 3 4	52 2 24	10 10 3 12	137 1 0 16	171 6 1 20
10	10 3 26	65 3 16	13 3 2 8	171 6 1 20	214 3 0 4
12	13 0 20	79 0 8	15 16 1 4	205 11 2 24	256 19 2 16

N.B. By the above table may be found how much yarn can be spun by any number of spinners in any given time whatever.

TABLE XV.

Shewing the Number of Threads to work *per* Hook, both in the Shank and Tapers, in making three-strand taper hawser-laid Cordage of the Sizes undermentioned, and the Lengths thereunto prefixed, with the Lengths of Yarn required to be warped for the fane, and the Distance to be observed between the Tapers; grounded upon 18, 20, and 25-thread Yarn, and tapered two-thirds the Length, and two-thirds the Size of the Rope.

Fathoms demanded.	Lengths of Yarn in Shank or whole first Taper.	Lengths of Yarn in the Taper.	Distance between the Tapers.											
	fms. ft.	fms. ft.	fms.	ft. in.	3	4	5	6	7	8	9	10	11	12
5	7 3	2 3	5	6 0	18	24	30	36	42	48	54	60	66	72
10	15 0	5 0	10	12 0	36	48	60	72	84	96	108	120	132	144
15	22 3	7 3	15	18 0	54	72	90	108	126	144	162	180	198	216
20	30 0	10 0	20	24 0	72	96	120	144	168	192	216	240	264	288
5	7 3	2 3	5	6 0	18	24	30	36	42	48	54	60	66	72
10	15 0	5 0	10	12 0	36	48	60	72	84	96	108	120	132	144
15	22 3	7 3	15	18 0	54	72	90	108	126	144	162	180	198	216
20	30 0	10 0	20	24 0	72	96	120	144	168	192	216	240	264	288
5	7 3	2 3	5	6 0	18	24	30	36	42	48	54	60	66	72
10	15 0	5 0	10	12 0	36	48	60	72	84	96	108	120	132	144
15	22 3	7 3	15	18 0	54	72	90	108	126	144	162	180	198	216
20	30 0	10 0	20	24 0	72	96	120	144	168	192	216	240	264	288

Suppose you want to make a rope either cable or hawser-laid, to be tapered one-third the length, and one-third the size; you must refer to Table V. or XIV for making taper-cable, or hawser-laid cordage, two-thirds the length and two-thirds the size, which you must work almost wholly the reverse way, by working the number of threads there mentioned to be worked in the tapers in the shank, and the number of threads in the shank must be worked in the tapers: the length of yarn there mentioned to be tapered must be the length in the head to the first taper, and the length

there mentioned in the head must be the length of the yarn to be tapered: the length of yarn requested to be warped for the shank will be the same as there mentioned, and the distance between the tapers will, in almost all cases, be the same as there nominated; but if at any time there should be a difference, and you are at a loss to find the distance between the tapers you must divide the length of yarn to be tapered by the number of threads you have to taper, and that will give the exact distance between them.

TABLE XVI.

Shewing the Number of Threads to work *per* Hook for four-strand hawser-laid Cordage, from 2 to 12 Inches in Circumference, of the Sizes of Yarn as undermentioned: the Ropes to be laid without Hearts, the Yarns comprising which being equally divided in the Strands.

No. of Threads here mentioned to weigh 99 to 100lb.	16	17	18	19	20	21	22	23	24	25
Size in Inches.	Threads <i>per</i> Hook.									
2	5	6	6	6	7	7	7	8	8	8
4	22	23	24	25	26	27	29	30	32	33
6	48	51	54	57	60	63	66	69	72	75
8	84	90	96	101	107	112	117	122	128	133
10	133	142	150	158	167	175	183	192	200	208
12	192	204	216	228	240	252	264	276	288	300

TABLE XVII.

Shewing the Length of Yarn requested to be warped for the undermentioned Lengths of four-strand hawser-laid Cordage, with the Hardening Mark prefixed against each respective Length.

Fathoms demanded.	Length of Yarn required.	Hardening Mark.
	fms. ft. in.	fms. ft. in.
10	15 2 6	12 2 0
20	30 5 0	24 4 0
40	61 4 0	49 2 0
60	92 3 0	74 0 0
80	123 2 0	98 4 0
100	154 1 0	123 2 0
120	185 0 0	148 0 0
130	200 2 6	160 2 0

Remarks.—It is very seldom that hawser-laid cordage is composed of more than four strands, but for the sake of experiment, or otherwise, it might be demanded to contain a greater number: as such, the following rule, carefully attended to, will inform our readers how to lay a hawser-laid rope in as many strands as may be considered expedient.

Suppose you want a five-strand hawser-laid rope, you must square the size of the rope proposed to be made; that product multiply by the size yarn you propose making your rope from; the product of which, divided by 15, will give the number of threads to work *per* hook for a five-strand hawser-laid rope. If you want to make a six-strand hawser-laid rope, you must proceed as above, and divide by 18; if a seven-strand, divide by 21; if an eight-strand, by 24; and so on, adding 3 to your divisor for every strand you mean to increase in the rope.

The shrinking proportion in making four-strand hawser-

laid cordage, in the first process, is exactly the same as in three-strand; the only difference is in closing the rope, which, being composed of four strands, occasions the rope to lay more round and close than in three-strand cordage, which makes the shrinkage be in a much greater proportion. The rope, in closing, will shorten $\frac{1}{4}$ th parts of the remaining length of yarn, after the rope is hard, instead of $\frac{1}{8}$ th, as in three-strand hawser-laid cordage.

The weight of each coil of four-strand hawser-laid cordage may be nearly ascertained, by referring to the table of the weight of three-strand (Table XII.), there being as near the number of threads in each size rope as can possibly be laid, for each strand to have an equal number. But it should be remembered, that a coil of four-strand hawser-laid rope, made out of 200 fathoms of yarn, will be only 130 fathoms long, instead of 133.2, as in three-strand hawser-laid cordage.

TABLE XVIII.

Shewing the Shrinking Proportions of the Yarn, in making the undermentioned Lengths of Bolt-Rope; also its Weight (untarred), from 1 to 8 Inches in Circumference.

Length in Fathoms of Rope demanded.	Length of Yarn required in Fathoms.	The Sledge should move to the following Marks from the Tackle-Post, and is called the Rope's Hardening-Mark.	1-Inch.	2-Inch.	3-Inch.	4-Inch.	5-Inch.	6-Inch.	7-Inch.	8-Inch.
			Weight.	Weight.	Weight.	Weight.	Weight.	Weight.	Weight.	Weight.
		Fms. feet.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.	C. qr. lb. oz.
10	14	11 4	0 0 2 6½	0 0 7 11	0 0 16 12½	0 1 1 5½	0 1 18 2½	0 2 11 2	0 3 6 10	1 0 7 2½
20	28	23 2	0 0 5 0½	0 0 15 6	0 1 5 9½	0 2 2 11½	0 3 8 5	1 0 22 4	1 2 13 4	2 0 14 5
40	56	46 4	0 0 10 1	0 1 2 12	0 2 11 1½	1 0 5 7	1 2 16 10	2 1 16 8	3 0 26 8	4 1 0 10
60	84	70 0	0 0 15 1½	0 1 18 2	0 3 16 10	1 2 8 2½	2 1 24 15	3 2 10 12	4 3 11 12	6 1 14 5
80	112	93 2	0 0 20 2	0 2 5 8	1 0 22 3	2 0 10 14	3 1 5 4	4 3 5 0	6 1 25 0	8 2 1 4
100	140	116 4	0 0 25 2½	0 2 20 14	1 1 27 11½	2 2 13 9½	4 0 13 9	5 3 27 4	8 0 10 4	10 2 15 9
120	168	140 0	0 1 2 3	0 3 8 4	1 3 5 4	3 0 16 5	4 3 21 14	7 0 21 8	9 2 23 8	12 3 1 14
Coil 143	200	166 4	0 1 8 0	0 3 26 0	2 0 16 0	3 3 0 0	5 3 16 0	8 2 8 0	11 2 8 0	15 0 24 0

Remarks.—In hardening the strands, the yarn will shrink one-sixth part of the whole length, which is called the rope's hardening mark.

In laying the rope, the strands will shrink one-seventh part of the remaining distance, which brings the rope to the length required.

N. B. Bolt-rope is usually made of 20 or 25-thread yarn, and generally delivered from the rope-maker white;

the process of tarring it being usually performed by the sail-maker, and is called flogging it, it being done in a stove or oven calculated for the purpose. In laying up your work, you must work with the same number of threads as in common hawser-laid cordage. Bolt-rope, for exportation, is sometimes lightly tarred; in which case, in calculating the weight, you must add one-sixth to the weights hereunto annexed.

TABLE XIX.

Shewing the Number of Threads to work *per* Hook for three-strand hawser-laid white Cordage, from 1 to 12 Inches in Circumference, of the undermentioned Sizes of Yarn, with the Weight of each Rope prefixed.

No. of Threads here men- tioned to weigh 88 lbs.	16	17	18	19	20	21	22	23	24	25	Weight of each Rope 133.2 Fathoms long.
Size in Inches.	Threads <i>per</i> Hook.										C. qr. lb.
1	3	3	3	3	3	3	3	4	4	4	0 1 12
2	8	8	9	9	10	10	10	11	12	12	1 0 8
3	18	19	20	21	22	23	24	25	26	27	2 1 12
4	32	33	35	37	39	41	42	44	46	48	4 0 20
6	72	76	80	84	88	92	96	100	104	108	9 1 20
8	128	135	142	149	156	163	170	177	185	192	16 2 24
10	200	211	222	233	244	255	266	277	289	300	26 0 16
12	288	304	320	336	352	368	384	400	416	432	37 2 24

N. B. Especial care should be taken relative to making white cordage for tackle-falls, crane-ropes, &c. that the hemp be of the very best quality; and that the same be topped, *viz.* all the short hemp taken out by the hatcheller;

and that the spinner do spin his yarn for the same exceeding smart and even, by no means lighter than the weight specified under the article *spinning the yarn*: if he does, his rope will not answer the size required to be made.

TABLE XX.

Shewing the Number of Threads to work *per* Hook for four-strand hawser-laid white Cordage, without Hearts, from 2 to 12 Inches in Circumference, of the Sizes of Yarn as undermentioned.

No. of Threads here mentioned to weigh 88 lbs.	16	17	18	19	20	21	22	23	24	25
Size in Inches.	Threads <i>per</i> Hook.									
2	6	6	7	7	7	8	8	8	9	9
3	13	14	15	15	16	17	18	19	19	20
4	24	25	26	27	29	30	32	33	35	36
5	37	39	41	43	45	47	49	51	54	56
6	54	57	60	63	66	69	72	75	78	81
8	96	101	107	112	117	122	128	133	139	144
10	150	158	167	175	183	192	200	208	217	225
12	216	228	240	252	264	276	288	300	312	324

N. B. The weight of the above ropes may be found by consulting Table XVII. for three-strand hawser-laid white cordage; the number of threads in each rope of a size being of an equal number, as near as possible.

Cordage made by Contract for the Use of His Majesty's Navy.—The under-mentioned shews the number of threads to work *per* hook; the lowest weight, allowance in weight, bandage, and highest weight; the cordage is to be received and allowed for by the receiving officers of his majesty's re-

spective dock-yards, under the honourable commissioners of his majesty's navy, to rope-makers who have made cordage (upon the usual principle) by contract, in coils, hawsers, cablets, and cables, with the length of yarn to be warped for the same, and length of cordage when made, as ordered by the honourable navy-board.

N. B. The highest weight a hawl of yarn for each sort of cordage should weigh (and by no means more,) is here noted.

TABLE XXI. Cablets.

Size	Threads <i>per</i> Hook.	Lowest Weight.	Allowance in Weight.	Bandage.	Highest Weight.
		C. qr. lb.	C. qr. lb.	C. qr. lb.	C. qr. lb.
2	3	1 1 4	0 0 4	0 0 4	1 1 12
2½	4	1 3 0	0 0 5	0 0 5	1 3 10
3	6	2 2 1	0 0 7	0 0 8	2 2 16
3½	8	3 1 2	0 0 10	0 0 11	3 1 23
4	10	4 0 18	0 0 12	0 0 13	4 1 15
4½	12	5 0 23	0 0 15	0 0 16	5 1 26
5	15	6 2 1	0 0 18	0 0 20	6 3 11
5½	18	7 3 7	0 0 22	0 0 24	8 0 25
6	21	9 0 12	0 0 26	0 1 0	9 2 10
6½	24	10 1 19	0 1 1	0 1 4	10 3 24
7	28	12 0 18	0 1 6	0 1 9	12 3 5
7½	32	13 3 16	0 1 11	0 1 14	14 2 13
8	37	16 0 6	0 1 17	0 1 21	16 3 16
8½	42	18 0 27	0 1 23	0 2 0	19 0 22
9	47	20 1 17	0 2 1	0 2 7	21 1 25
9½	52	22 2 9	0 2 7	0 2 13	23 3 1

It is to be observed, that the above sizes in Tab. XX., viz. 2 to 9½ inches, are termed, in the navy contracts, cablets, the yarn for which should be warped 200 fathoms long, and the cablets, when complete, to be 120 fathoms. A hawl of yarn containing 336 threads, should weigh from 16 cwt. 0 qr. 8 lb. to 16 cwt. 1 qr. 25 lb., and no more, allowing one-sixth part of such weight for tar, which is the allowance made by the honourable navy-board, and no more.

TABLE XXII. Cables.

Size.	Threads <i>per</i> Hook.	Lowest Weight.	Allowance in Weight.	Highest Weight.
		C. qr. lb.	C. qr. lb.	C. qr. lb.
10	58	21 0 23	0 2 3	21 2 26
10½	64	23 1 17	0 2 9	23 3 26
11	70	25 2 10	0 2 15	26 0 25
11½	76	27 3 4	0 2 22	28 1 26
12	83	30 1 10	0 3 1	31 0 11
12½	90	32 3 17	0 3 8	33 2 25
13	98	35 3 9	0 3 16	36 2 25
13½	106	38 3 1	0 3 25	39 2 26
14	114	41 2 20	1 0 5	42 2 25
14½	122	44 2 12	1 0 12	45 2 24
15	130	47 2 3	1 0 21	48 2 24
15½	139	50 3 7	1 1 2	52 0 9
16	148	54 0 13	1 1 11	55 1 24
16½	157	57 1 16	1 1 20	58 3 8

Cablets from 4 to 9½ inches will not be rejected, if they are half an inch in girth above the dimensions ordered.

The yarn for the above cables (Tab. XXII.) are warped 166 fms. 4 ft. long, and the cables, when complete, to be 100 fathoms long. A hawl of yarn containing 336 threads, 166 fms. 4 ft. long, should weigh from 13 cwt. 2 qr. 6 lb. to 13 cwt. 3 qr. 16 lb., and no more, tarred with the same proportion of tar as the yarn for the cablets before-mentioned.

Cables 10 inches and upwards, are allowed three-fourths of an inch in girth more than the dimensions given.

In proportions of cordage wherein the cables contained in them do not exceed $13\frac{1}{2}$ inches in circumference, a proportion of $1\frac{1}{2}$ cwt. of spun-yarn is allowed to be sent to every ton of cordage; but if the cables are 14 inches in circumference and upwards, then 3 cwt. for every ton is allowed, in order to work up the toppings (or hemp) which should be taken out of the hemp agreeable to contract, previous to its being spun into cable-yarn (in particular), as it frequently happens that the great number of lives of some of his majesty's most valuable subjects are at stake upon the dependance of a single cable.

The cables made in the usual mode, by contract, have of late never exceeded $16\frac{1}{2}$ inches in circumference, (Tab. XXII. extends no further): for all the higher sizes are made by patent machines, by which much manual labour is spared, and the yarns and strands laid much closer and more even, and bear the strain more equally.

Size.	Threads per Hook.	Lowest Weight.	Allowance in Weight.	Bandage.	Highest Weight.
		C. qr. lb.	C. qr. lb.	C. qr. lb.	C. qr. lb.
$\frac{3}{4}$	2	0 1 4	0 0 1	0 0 1	0 1 6
1	3	0 1 20	0 0 1	0 0 1	0 1 22
$1\frac{1}{2}$	6	0 3 13	0 0 2	0 0 2	0 3 17
2	9	1 1 6	0 0 4	0 0 4	1 1 14
$2\frac{1}{2}$	14	2 0 5	0 0 6	0 0 6	2 0 17
3	20	2 3 20	0 0 8	0 0 9	3 0 9
$3\frac{1}{2}$	26	3 3 7	0 0 11	0 0 11	4 0 1
4	35	5 0 14	0 0 14	0 0 16	5 1 16
$4\frac{1}{2}$	44	6 1 22	0 0 18	0 0 20	6 3 4
5	54	7 3 19	0 0 22	0 0 24	8 1 9
$5\frac{1}{2}$	65	9 2 2	0 0 27	0 1 1	10 0 2
6	77	11 1 3	0 1 4	0 1 7	11 3 14
$6\frac{1}{2}$	91	13 1 11	0 1 9	0 1 13	14 0 5

The sizes of cordage hereunto annexed, from $\frac{3}{4}$ to $3\frac{1}{2}$ inches in circumference, are termed, in the navy, contract coils; all above, viz. 4 to $6\frac{1}{2}$ inch, are called hawfers. The yarn for both coils and hawfers should be warped 195 fathoms long, and the ropes, when completed, are to be 130 fathoms long. A hawl of yarn, consisting of 336 threads, 195 fathoms long, should weigh from 16 cwt. 1 qr. 7 lb. to 16 cwt. 2 qr. 24 lb. and no more, tarred in the same proportion as cablets and cables.

All cordage delivered into his majesty's dock-yards undergo a trial, which is, by proving one strand out of each rope, each thread (or yarn) of which having a weight, weighing one-third of an cwt. made fast to it, which it should lift; but if a certain number of yarns (according to the size of each rope) should break in the trial, the rope is rejected, otherwise it is received.

Particular attention should be paid not to send any kind of cordage into his majesty's dock-yards above its highest weight, allowed according to contract, as, in such case, all above that weight will be a loss to the manufacturer; the receiving officer not being authorised to allow any more than is specified in the contract.

N. B. It is to be observed, that, in making cordage by contract for the use of his majesty's navy, his majesty finds his own hemp, the contractor tar and labour at a certain price per ton. All cables and cordage to be tarred with good Stockholm tar, without mixture of any

other, except about one-third part, which may be of Russia tar.

A white thread, twisted the contrary way, (sometimes called the rogue's yarn,) is to be laid in all the strands of the cables and large cordage; and a twine in the small cordage for the king's mark, so as to be seen on the outside of the strands.

In any of the strands, there is to be no greater number of threads at the ends of the cables or cordage than in the middle.

The only parliamentary regulations, relative to the manufacture of cordage, are contained in the following act; "An act for more effectually preventing deceits in the manufacturing of cordage for shipping; and to prevent the illicit importation of foreign-made cordage." 25 Geo. III. c. 56.

In July 1799, a patent was granted to W. Chapman and E. W. Chapman, of Newcastle-upon-Tyne, for their improved method of making cords and ropes, twined and untwined, from the spinning of the yarn inclusive, to the finishing of the rope or cordage. This invention appears, by the specification, to include material improvements in the spinning of rope-yarn, and in the manufacturing of cordage. Rope-yarns are at present spun by men, at an expence of from half a crown to five shillings per day, according to the situation of the place, whether in the out-ports, or on the river Thames. Or it is wholly spun by machinery.

In the practice of the first method rope-walks are necessary, and the fibres of the hemp are drawn into the yarn of different lengths proportionate in a given degree to their position in the outside or inside of the yarn; accordingly, when this yarn is strained, and its diameter collapses, the inside fibres of hemp bear the greatest strain, and thus they break progressively from the inside.

In the spinning by a mill the fibres are all brought forward in a position parallel to each other, previously to their receiving their twist. They are consequently all of one length; and, when twisted, the outside fibres are most shortened by forming the same number of spirals round a greater axis than the interior, and thus they must consequently break the first, on the same principle that the outside yarns of strands of ropes manufactured in the old method break before the interior yarns; and, consequently, with less strain than ropes of the improved principle, where the strands, (or immediate component parts of the rope) have been formed in such a manner as that all the yarns shall bear equally at the time of the rope's breaking.

Nevertheless, yarns spun by a mill have been found stronger than common yarns, on account of the great evenness with which they are spun; the manual labour in manufacturing is much less than in the common method; but, on the other hand, there is the expence of machinery, and the greater waste of hemp in preparing it for being drawn out in the progressive stages of its advance to the spindle.

The method invented by Messrs. Chapman differs from both the preceding, in having, by an easy and simple contrivance, the fibres of the hemp laid in the yarn in such a manner as the yarns themselves are laid in the strands of the rope manufactured on the new principle.

Their machinery consists only of a spindle, divided into two parts, the upper containing apparatus to draw forward the hemp from the spinner with twist sufficient to combine the fibres; which enables them to employ women, children, and invalids, and also to appropriate the rope-ground solely to the purpose of laying ropes.

The part we have described is only an improvement on

the methods of spinning, granted to Mr. William Chapman on the 8th day of November, 1798.

The remaining parts of their invention consist chiefly in the giving, from a stationary power, internal motion to a locomotive machine, *viz.* to the roper's sledge, on which the strands and the rope itself are twisted, by which contrivance they are enabled to apply a water-wheel, or steam-engine, to the whole process of making ropes of all kinds whatever.

Mr. Joseph Huddart of Ilington obtained a patent in August of the same year for an improved method of registering or forming the strands in the machinery for the manufacture of cordage. Having previously taken out a patent for this purpose, he contrived to effect it by the following means :

1. By keeping the yarns separate from each other, and drawing them from bobbins, which revolve, to keep up the twist whilst the strand is forming.

2. By passing them through a regiller, which divides them by circular shells of holes ; the number in each shell being agreeable to the distance from the centre of the strand, and the angle which the yarns make with a line parallel to it, and which gives them a proper position to enter.

3. A cylindrical tube, which compresses the strand, and maintains a cylindrical figure to its surface.

4. A gauge to determine the angle which the yarns in the outside shell make with a line parallel to the centre of the strand when registering ; and, according to the angle made by the yarns in this shell, the length of all the yarns in the strand will be determined.

5. By hardening up the strand, and thereby increasing the angle in the outside shell, which compensates for the stretching of the yarns, and the compression of the strand.

The patent which Mr. Huddart took out in August relates to the invention of a machine that may be worked by men, or any other power, and by means of which the registering may be commodiously and effectually carried on. But figures are necessary for describing intelligibly his peculiar contrivance. Mr. Huddart, in the following year, took out a patent for improvements in the method of turning cordage in the manufacture of it. But our limits forbid our enlarging on this article. The specifications of the patents for registering, as well as fastening, may be consulted by those who are concerned in this manufacture.

Rope Walk, or Rope-house Ground, is the place where ropes are manufactured. This should be 400 yards long, and about 10 broad. At the upper end are fixed the spinning-wheels, over which is the hatchelling-loft, also the back-frame wheels, tackle-boards, and posts, winches for winding the yarn on as it is spun, and reels on which to reel the ropes. On each side are flax-polls ; in the middle is fixed the warping-post, and at the lower end, the capstern and reaching-post. Back-frame wheels for small, and sledges and drags for large ropes, are used towards the lower end ; the back-frame wheel, for laying cordage from a six-thread ratline to a two-inch rope, is about four or five feet in diameter, and is hung between two uprights, fixed by tenons on a truck, and supported by a knee of wood. Over its top is a semicircular frame, called the head, to contain three whirls (that turns on the brasses) with iron spindles, secured by a hasp and pin. They are worked by means of a leather band encircling the whirls and the wheel. Three of the whirls are turned when hardening the strands, and one only when closing the rope, the strands being hung together upon it. The truck, on which the back-frame wheel is fixed, runs on four wheels, and is

made of three-inch oak plank, about nine feet long and thirteen inches broad at one end, and eleven inches broad at the other. The capstern, about eight feet high, and fourteen inches in diameter, is turned either by men or horses ; its use is to draw the yarn, when tarring, out of the copper, through the nipper, to be coiled away in the yarn-house, and there properly hardened before it is used ; otherwise it will kink, *i. e.* twist or curl, by being twisted too hard in closing. Another capstern, or crab, is fixed at the lower end of the walk, for stretching the yarn to its fullest extent, before it is worked into strands, by means of the tackle-fall, led from the sledge to the capstern ; these being about eighteen yards distant from each other. The crank-wheel, which is used for spinning of lmes, box-cord, &c. is fixed on an iron spindle or axis, with a handle by which to turn it. It hangs between two posts, and in its upper part, above the wheel, is let in a semicircular board to receive three sets of whirl-bolts, with wheels upon them, on which the spinners hang their threads : at the front side of the wheel is a short post, supported by a knee of oak, on which the spindle rests. The *drags* resemble the hinder part of the sledge, to which they are fastened by ropes, and they are lined with a board on the upper side : their weight serves as a press, when the rope requires more than the sledge can carry properly to stretch the strands, and prevent their kinking. The *hatchel* serves to clear the ends of the hemp, by drawing it through, having forty sharp-pointed iron-teeth, similar to the hatchel in the *clearer*, which has finer teeth. Iron-jacks are sometimes used instead of the table-wheel or back-frame wheel, and differ from the latter by having an iron-wheel with cogs, which work in the whirls, that have likewise iron-cogs. The *loper*, which is used to lay lines, has two iron swivel-hooks (running round in a brass or iron box) at each end, for the line to hang on and work, by the power of the fore-turn, from the wheel at the upper end. The *nipper* is formed of two steel-plates, with a semi-oval hole in each, which, by the motion of the upper plate, enlarges or contracts as the tarring of the yarn requires. It is thus fixed : a post is placed between the kettle and the capstern, with a mortise cut eighteen inches long from the kettle's surface, and five inches wide. The under plate is turned up on each side, to form two grooves, and is let into the front side of the post from the lower part of the mortise. The upper plate has a dove-tail on the back, that slides up and down in a groove into the grooves of the lower plate ; and by a flasp, made fast to its front, it is raised or lowered, and regulated by a weight suspended at the other end, so that the yarn receives no more tar than is required, and that which is squeezed out drops into a trough, and returns into the kettle. *Press-barrels* are old tar-barrels filled with clay, and laid on the sledge or drag to add weight when the rope is closing. The *reaching-post* is a post in the ground at the lower end of the walk ; used in stretching the yarn by means of a tackle, one of the blocks of which is hooked to a strap round the post, the other block to a pendant at the sledge, being about eighteen yards distant from each other. *Sledges* are frames made of strong oak, clamped with iron in different parts ; the two sides are the length of the sledge, made of oak, and tied in with oak bars at each end ; near the front are two uprights, let into the sides, and supported by two slanting pieces from the upper end. A breast-board is fastened with iron pins to the uprights, and contains holes for the hooks to pass through, on which the hooks are hung ; which, being turned by men, is twisted into rope, and so closed or finished. These sledges are loaded as the occasion of making the rope requires. The *spinning-wheel* is hung between two posts

fixed in the ground; over its top is a semicircular frame, called the head, which contains twelve whirls, if it be for twelve spinners to spin at the same time; these whirls turn on iron spindles, with hooks to their front ends to hang the hemp on, and are worked by means of a leather band encircling the wheels and whirls. The tools and terms appropriate to rope-making are described in their proper places.

ROPE-Turn, the yarn of any rope untwisted. It commonly consists of cable-ends which are worn out; and are called *junks of the cables*. It serves for many purposes among the sailors.

Rope-yarn properly denotes the smallest and simplest part of any rope, being one of the threads of which a strand is composed; so that the *live* of the latter, and of the rope into which it is twisted, are determined by the number of rope-yarns.

ROPES, *Standing*, in a *Ship*, the shrouds and stays are so called, because they are not removed, unless to be eased or set taught. See **SHROUDS**, and **STAYS**.

ROPES, *Staple*, ropes made of hemp, not inferior to clean Peterburgh.

ROPE-Bands, braided cordage, used to fasten the heads of sails to their respective yards. See **ROBBINS**.

ROPE-Deck. See **DECK**.

ROPE, in *Agriculture*, a thick sort of cord formed of hemp, or other material; much used by farmers. See **CORDAGE**.

A very useful sort of rope for traces, and other similar purposes, has lately been formed of the coarse wool of sheep.

ROPE, *Cart*, that sort of rope used in loading hay, straw, or other bulky loads, by the farmer. These ropes should always be strong, and formed of the best materials, whatever the nature of them may be.

ROPE is also a word signifying to tether, as a horse, or other animal. It is a very injudicious practice, and one which should by no means be generally followed by farmers.

ROPE, *Cord*, or *Strap*, in the *Manege*, is any of these tied round a pillar, to which the horse is fastened, when they begin to quicken, and supple, to teach him to fly from the chambrier, and not gallop fastly or incomparably.

In those maneges where there is no pillar, a man stands in the centre of the ground, and holds the end of the rope.

ROPES, *Drag*, in the *Artillery*, are those by which the soldiers pull the guns backwards and forwards both in their exercise, and in an engagement. They are of various lengths and dimensions, as they are used for guns or howitzers of different weights.

ROPES, *Foot*. See **FOOT-ROPES**.

ROPES of two Pillars, are the ropes or reins of a cavesson, used to a horse that works between two pillars. See **PILLAR**.

ROPE-Dancer. See **DANCER**, and **NANCE**.

ROPE of Sand, a phrase familiarly used to denote disunion, or want of adhesion and continuity. In this sense it is applicable to a variety of cases, and in military language to the disagreement that subsists between the colonel and the captains of a regiment.

ROPE Machine for raising Water, in *Hydraulics*.—If a vertical grooved wheel, fixed in a frame, be situated within the water at the bottom of a well, and another similar wheel, having a handle affixed to its axis, be situated in another frame at the upper part of the well; also an endless rope (*viz.* a rope whose two extremities are spliced into each other) be passed round both wheels; then, on turning the handle, the wheels and the rope will be caused to move,

viz. the rope will ascend on one side, and will descend on the other, passing successively through the water of the well; but the ascending part will carry up a quantity of water adhering to its surface; and this water differs in quantity, according to the size of the rope, the depth of the well, and the quickness of the motion; *viz.* with a larger rope, in a less deep well and quickest motion, a greater quantity of water will be raised, than otherwise.

In order to intercept the water at the top of the well, the upper wheel is inclosed in a pretty large box, in the bottom of which there are two holes, through which the ascending and descending parts of the rope pass. To these holes are affixed two short tubes, which prevent the exit of the water which falls to the bottom of the box. There is also a lateral spout on the side of the box, close to the bottom, for the water to come out of; and on the broad sides of the box there are two holes for the axis of the wheel. The 9th and 10th figures of *Plate XIV. Hydraulics*, exhibit a section and a front view of a machine of this sort, which was put up in the year 1782, on the castle hill at Windsor, where the depth of the well is 95 feet. A similar machine was also placed on the round tower of Windsor castle, which draws the water from the depth of 178 feet.

The same letters refer to the like parts in both figures.

The wheel, H, at the bottom of the well is of lignum vitæ, one foot in diameter. Its axis is of steel, and turns with its extremities in sockets of bell-metal.

The frame, I I, is of iron.

The wheel, E E, at the top of the well is of iron; but its rim, with the groove which receives the rope, are of lead. The diameter of this wheel is three feet.

The axis, d d, is of steel, and its extremities turn in bell-metal sockets, which are fixed in two upright posts, A, A, that support the machine. T is the handle affixed to the axis, which handle describes a circle of 28 inches in diameter; b b is the wooden box, lined with lead, which incloses the wheel E. F, F, are the holes at the bottom of the box through which the rope passes. Their diameter is about two inches.

On the same axis, d d, another wheel, C C, of about four feet in diameter, is fixed. This wheel is of wood, loaded on the edge with lead, and it serves as a fly to facilitate the motion.

The rope is of horse-hair, and measures half an inch in diameter.

With this identical machine, several experiments were tried, the result of which is as follows:

When the machine was worked slowly, *viz.* so as to make about 30 revolutions of the handle in one minute, then very little water came up adhering to the rope; and of this water a very small portion was separated from the rope within the box, so as to come out of the spout Z, in the side of the box.

When the revolutions of the handle were about 50 in a minute, then a considerable quantity of water came up adhering to the rope; and on turning the wheel E E round, the greatest part of that water, having acquired a considerable velocity, flew off in a tangent from the rope, and formed a jet within the box. This water, falling to the bottom of the box, came out of the spout Z.

It was found, that the utmost exertion of an ordinary working man could not make more than 60 revolutions of the handle in a minute; in which case the rope moved at the rate of about 16 feet *per* second. With this velocity the quantity of water that came out of the spout, Z, was about six gallons *per* minute: but it would have been im-

possible for the man to have worked at that rate for more than three or four minutes.

This machine may evidently be placed afloat, viz. so as to convey the water from one place to another, which is not quite perpendicularly over the former. The same construction, and almost the same expence, will adapt the machine to wells of different depths, though the effects will not be always the same.

More than one rope, or a broad band instead of a rope,

might be adapted to this machine, for which purpose, the wheels must have more than one (or a broad) groove, &c.

The greatest disadvantage of this machine is, that the rope does not last long. Its being always wet destroys it very soon. In putting on the rope, care must be had to soak it well in water before it be spliced; otherwise it will either be too tight, or it will break. A hair rope has been found to last longer than one of hemp. See Cavallo's Elem. of Nat. and Exp. Philosophy, vol. ii.

Rose engine

ROSE Engine, Rose lathe, or Figure lathe, in the *Mechanic Arts*, is a machine used for turning any articles in wood, ivory, or metal, in the same manner as a common lathe, but it has additional parts, by which the surface of the subject which has been turned, can afterwards be engraved with a great variety of patterns of curved lines, which, in general, are denominated from the French *rosette*, from a slight general

resemblance which they have to a full-blown rose, and hence the machine is called a rose engine.

This machine, as we have said, contains all the parts of the *lathe*, (see that article,) and in the same manner as in turning, the work is caused to revolve, whilst the cutting tool is kept stationary; but the difference between the rose

lathe and the common lathe is, that in the former the centre of the circle, in which the work revolves, is not a stationary point, but a slight motion is given to the centre whilst the work is revolving upon it, the tool being all the while stationary; the surface of the figure which it forms will be, of course, out of round, *i. e.* it will deviate from the circular figure as much, and as often, as the motion is given to the centre.

The art of turning curiosities in wood or ivory, is one of those which is best adapted, of any of the mechanic arts, as an amusement for persons who either have leisure to apply to such subjects, or who require relaxation from mental studies: it has long been a favourite pursuit of many gentlemen, and the machines they employ are very ingeniously constructed. The curious in this art reckon two points of perfection in their works, one where the extreme delicacy, or elegance, of the object renders it admirable, and the other is considered from the difficulties of the execution; the former may be judged by all persons possessed of good taste, but to judge of the latter requires some knowledge of the art, or, at least, so far as to know that the lathe will form only such articles as are perfectly circular, all the parts having a common axis; therefore the specimens of turning are to be more or less esteemed, in proportion as they are more opposed to the circular figure. This art was more cultivated a hundred years ago than at present, and more curious specimens were then produced, such as hollow balls of ivory, containing many excentric figures, formed within each other, all being cut from the same solid piece, and every one beautifully ornamented upon the surface, although only small holes were left through them to gain access to the interior ones: this was carried so far as to form twelve balls of ivory one within the other. A great collection of curiosities of this kind will be found in a French work entitled "*Récueil d'Ouvrages Curieux dans le Cabinet de M. Grollier de Servir*," 4to. Lyons, 1719. This contains drawings of some very curious articles; but although the art is not so generally practised at the present day as formerly, the machines which are now invented are vastly superior, and, with the same attention, would doubtless admit of the curiosities being equally extended. Messrs. Holtzapffel and Deyerlien, of Cockspur-street, London, have made many improvements in the construction of rose engines, which they execute, as well as all other tools, for ornamental turning, in the most finished style. We have obtained drawings of one of these, see *Plate III. Engines*, in which *fig. 6.* is an elevation in front of the machine. *A A B B* is the wooden frame; *D*, the large foot-wheel, to give motion to the mandrel, or spindle, *T T*, by the band and pulley *F*. The work is fixed in a chuck *I*, at the extremity of the mandrel; and the tool is held by the slide-rest *K*, which, though it has the means of moving the tool a small quantity, to adjust it to the radius of the rose, or figure intended to be cut, still it will firmly retain the position in which it is placed. The upper part, *A*, of the frame of the machine is made of mahogany, but has within it a cast-iron frame, consisting of two bars, or bearers, which being placed parallel, and at a small distance asunder, leave a groove or opening between them, in the same manner as the cheeks of any other lathe, for the reception of the tenon, at the lower end of the back puppet (shewn by the dotted lines) *L*, which is used to support the end of a long piece of work; though this is seldom used, because the work can only be turned circular, when the back centre supports it. All work which is to be figure-turned must be held in a chuck, screwed on to the end of the mandrel *T*; because it is only the mandrel which is moveable, to give those deviations from the circular figure, which are necessary to form the

figured work. For this purpose, the two standards, *G* and *H*, which support the mandrel, are not firmly fixed to the bed, *A*, of the machine, as in other turning-lathes; but they descend between the cheeks or cast-iron bed, almost as low as the bottom of the mahogany bed *A*, and have there an axis *P* (dotted), which is parallel to the mandrel, and supported on pivots at its ends; these pivots being received in pieces of cast-iron, descending from the cheeks, and strengthened by the iron bar, *Q*, extended between them. The two standards, *G*, *H*, are formed of one piece, and have a strong bracing of iron between them, in addition to the axis *P*; but this cannot be seen in the figure, because it is concealed between the cheeks of the bed *O*. The oscillating motion is given to the mandrel by means of metal rosettes *M*: these are wheels, fixed upon the mandrel, each having its periphery indented and curved with a waving line, as shewn at *M*, *fig. 7.* The rosettes are acted upon by a small roller, placed at the end of a piece *n*, which is supported by a triangular bar *m*, fixed parallel to the mandrel, upon the upper ends of curved arms, as shewn in both figures. Now it is evident that when the mandrel revolves, the eminences and depressions of the rosette, applying themselves to the roller of the piece *n*, which is stationary, will cause a vibrating or oscillating motion of the mandrel, and the frame, *G H*, which contains it. A strong spring is placed within the cavity of the bed *A*, and applied to the frame of the mandrel; so that it inclines the latter always towards the central or vertical position, that is, the position, when the line of the mandrel is produced, would pass exactly through the point of the screw of the back puppet *L*; therefore, when the protuberant or waved parts of the rosette causes the mandrel to depart from this situation, the spring will be bent, and ready to force it back, the instant the curvature of the rosette will permit. The spring is slightly curved, and placed in the space between the insides of the iron cheeks of the bed and the frame of the mandrel, so that the middle of the curved part acts thereupon, and the two ends bear against the inside of the frame, to give the re-action. Seventeen different rosettes are placed upon the mandrel, as shewn in a cluster at *M*, each being of a different pattern. Several are of the kind shewn in *fig. 7*, that is, scooped out with waves or concave depressions, but differing in the number of waves from 12, as in the figure, to 144, which will, therefore, be very minute. The socket for the piece *n* can be fixed, by its clamp screw, upon any part of the triangular bar *m*, to bring it opposite any one of the rosettes which is required to be used. Other rosettes, instead of having waves or concave depressions, as shewn in *fig. 7*, have convex protuberances. In either case, when the pattern is very fine, the roller upon the end of the bearing-piece, *n*, cannot be admitted, because its curvature would not be sufficiently rapid to suffer it to fall into the depressions. In these cases, therefore, the end of the piece *n* is used for the contact, being rounded, and well hardened and polished, to diminish as much as possible the friction of the rosette revolving, whilst in contact with it.

The slide-rest, which supports the tool, is next to be described: the manner in which it applies to a piece of work, when fixed in a chuck at the end of the mandrel, is shewn in *fig. 6*, whilst *figs. 11* and *12* are on a larger scale to describe it minutely. The rest can be fastened at any part of the bed, by the lower part of the foot, which is supported on the bed, *A*, of the lathe, and is divided with a dove-tailed groove in the under side, to receive the head of a screw-bolt, going down through the lathe-bed, and fixing it at any place by a thumb nut, as shewn at *k*, *fig. 6*; the groove in the foot is for the purpose of allowing the rest to be moved to and from the

centre of the lathe, to adjust it to the diameter of the work which is turning. The foot has a strong cylindrical pin fixed upright in the end of it, and this is fitted into a corresponding socket S, formed out of a solid piece, with the lower slider K of the rest; a clamp-screw in the side fixes the socket fast upon the pin, and there is a wheel *s*, cut with notches, at the bottom of the socket, with a catch *t*, fixed upon the foot R, to engage its teeth and hold it fast; by which means the sliders, K, can be fixed, and held fast at any required angle with the mandrel, for purposes we shall hereafter mention.

The upper part of the slide-rest consists of two horizontal sliders, K and *g*, placed in directions perpendicular to each other; to one of these the tool is firmly attached, and by means of screws with handles, the sliders and the tool can be moved in any direction, to follow the tool to the work; K, in both figures, is a frame of metal, formed from the same piece as the socket S; its upper surface is made flat, and upon this a slider, or flat plate, *ee*, is fitted, to move with freedom and precision. A screw is mounted in the opening of the frame, and is tapped into a piece of metal, projecting from the lower side of the slider, so that the screw, when turned round by a handle *d*, fitted on its square end, advances, or draws back the slider, which is guided in a right line by two pieces of brass, screwed to the under side of it, to form a dove-tailed groove, to which the edges of the frame K are fitted very accurately: upon this slider a frame, or two rulers, are screwed, having a second steel slider *g*, fitted in the dove-tailed groove formed between them, and provided with a screw *i*, as the former, to move it. This upper slider carries a piece of metal, with a square hole through it, in the direction of its length, to receive the tool *k*, and a screw at top to fasten it in. The slide-rest being mounted in the manner of *fig. 6*, upon the bed of the lathe, the upper slider, *g*, is parallel with the mandrel, and the lower one perpendicular thereto. For turning flat or face work, the tool is put as there shewn. Now, by turning the screw, *i*, of the upper slider, the tool advances to a contact with the work, which is mounted in a chuck, as in the figure; then by the other screw, *d*, it is moved across the face of the work, turning it as it proceeds to a perfectly flat surface. For turning a cylinder, mounted between centers, the slide-rest is to be turned one quarter round upon the pin in the socket S, so that the upper slider will be perpendicular to the mandrel, and the lower one parallel thereto; in this case, the upper slider must be moved, to adjust the tool to the diameter of the intended work, and the lower slider is moved by its handle *d*, to carry the tool along the length of the cylinder, and cut it as it goes. The whole rest can be fixed at any part of the bed, and can be moved instantly if required. The slide-rest will also turn cones by the following contrivance: the plate, or dove-tailed groove supporting the upper slider, *g*, may be turned round upon the plate *ee*, and fastened at any inclination by a screw passing through a circular groove in the plate. By this means, the upper slider is inclined, in any required angle, to the mandrel, and will then turn a cone, either hollow or solid. The slide-rest presents the tool so firmly to the work, that it will not retreat in the least when any protuberance comes by, but cuts it away, if the strain is not so great as to break the tool: but of this there is no danger if it be properly managed, because the screws advance the tool so slowly, that there is no need to push it forwards suddenly, as it is often unavoidable in turning by hand. The sliders are often divided into inches and subdivisions, by which the work can be made exactly to any dimensions without trouble, or two things may be fitted exactly together. The upper slider, *g*, has a graduated arc to

shew the angle of inclination which it makes with the lower one, when set for turning cones, so that a hollow cone being bored out in a chuck, a solid plug may at once be turned to fit it, without trial, the rest making it certainly of the true angle.

The lathe is put in motion either by the hand, or by the foot of the turner. The latter, when the work is to be turned or reduced to the circular figure, as in any common lathe; and the former, when the work, after being turned, is to be ornamented, an operation which, from its delicacy, requires a very regular motion.

When the machine is turned by the foot, it is done by the pressure upon the treadle E, which acts upon the crank C, on the axis of the foot-wheel, or fly-wheel, D. The motion is communicated from the treadle by a crank-hook, or connecting rod, *a*, fastened to the crank of the wheel, by a collar embracing and turning round at the upper end. When the foot pushes down the treadle, it gives the wheel a rotative motion; and when the crank has been drawn to the lowest point, the momentum which the wheel has thus acquired, draws up the treadle, and thus, by the alternate pressure of the foot, and the momentum of the wheel, the motion is regularly continued. The wheel is made of cast iron, and fixed on the extreme end of the axis; it has two rims of different sizes, and the surface of each is made conical, and cut with three annular grooves, which are recessed, with an angle at the bottom, so as not to have a flat bottom. This form is advantageous, on account of the band having more power to turn the wheel F. These different grooves are made, in order to give different degrees of velocity to the lathe, or to increase the power. The axle of the wheel is made of wrought-iron, except the pivots or centers, and it is bent in the middle to form the crank C: the pivots at the ends are made of hard steel, welded to the iron parts of the axle. The band which connects the fly and mandrel is made of catgut, of such thickness as the nature of the work may require, and is either spliced at the joining of the two ends, or they are fastened together by a steel hook and eye. The band may be either tightened, by shifting it to other grooves in the great wheel, or in the pulley F, of the mandrel; or otherwise by a sliding-piece in the leg B, which is regulated by a screw *x*.

The motion for the hand is given by a small handle O, *fig. 6*; this is fixed upon the end of a spindle, which at the other end carries a small wheel N, communicating by a band with the great wheel D. The spindle is supported in a frame, which is attached to the lathe-frame, by a centre or joint, on which it can be raised up, and fixed by a toothed sector, to tighten the band when it is required.

The pulley F has three or four grooves, of different sizes, to receive the band, and by this means the mandrel may be turned with different degrees of velocity, and made to accommodate itself to the length of the band. The wheel N is made in the same manner.

When a piece of work is to be made in the rose engine, it is first turned true to the size and figure, and then polished, before it is ornamented: therefore the machine is first set to turn circular. For this purpose, the piece *n*, *fig. 7*, is withdrawn, so as to be beyond the reach of the rosette, and a head at *z*, *fig. 6*, being turned, it shoots a double bolt, which locks the frame G H fast in its perpendicular position; that is, when the point of the back centre-screw L will be exactly in the line of the mandrel, the frame being thus rendered immovable, the machine will turn the same as any common lathe. If the work is of considerable length, it must be supported at the end by the back centre L, at least whilst it is turned circular, previous to being ornamented.

The back puppet, *L*, is made of cast-iron, and is fitted upon the cast-iron bearers, on which it can be fixed at the required distance from the mandrel by a vertical screw underneath, and a nut, which comes in contact with a horizontal plate or washer below the laid bearers. Its centre-screw has a sharp conical point to support the work, and there is a clamp-screw at top to fasten the centre-screw, to prevent it from running back.

The methods of fixing the work to the end of the mandrel whilst it is turned are very numerous, and vary in almost every instance: in general, it is held in a piece of wood, *I*, called a chuck, which is screwed upon the nose of the mandrel *T*, and being bored, or turned out in the manner of a cup, the piece of wood or ivory which is to be turned is driven into it by a mallet till it is firmly fixed: the wood is, of course, cut nearly to a circular figure, before it is fixed in the chuck; it is then wrought with a sharp triangular pointed tool, *b*, which being fixed in the rest, and advanced to the work by the screw *i*, cuts small contiguous grooves on the surface, till it has broken the grain of the wood, and removed all exuberances. The tool being gradually advanced by its screws *d* and *i*, as is required, the work is reduced at length nearly to its intended size and figure, but will be wholly covered with small grooves: to remove these, and render the work even, another tool is next used; this is formed like a narrow chisel, but made very thick, and with an obtuse edge, which is only bevelled on the under side: its edge will remove the eminences between the grooves left by the first tool. The work is then smoothed, by applying to it the edge of a piece of the blade of a broken knife bevelled away; this is held in the hand, and the work is followed up with it, that its sharp edge may scrape away any roughness left by the tools. To polish the wood, a piece of seal-skin, Dutch reed, or glass paper, is held by the hand upon the work as it runs round, and it cuts away a fine powder, making the work smooth enough to receive a polish. This is raised by first applying a piece of bees-wax, till the work is slightly covered with it, then afterwards burnishing or polishing it, by holding a flat piece of hard wood upon it. The finish can be given by the friction of a coarse woollen rag, lightly smeared with olive oil.

Ivory is turned nearly in the same manner, but is polished with chalk and water, and afterwards by the friction of a woollen cloth; or, if it is first touched with an oily rag, and rubbed off with a dry woollen cloth, it will have a very fine surface.

This is only the same process as is used for ordinary turning; but when the work is finished in this manner, the ornamenting is begun by releasing the bolt, *2*, of the mandrel-frame *G H*, and chusing the rosette best adapted to the pattern which is required. The piece, *n*, is set upon the triangular bar, to be in contact with its wave, and will thus give the oscillating motion, as before described; so that when the tool is applied to the work, it will produce a waved or indented surface, or outline, corresponding with the figure of the rosette, instead of the circular figure produced by the common lathe.

If the ornamenting is to be performed upon a flat surface, such, for instance, as the lid or top of a box, it is chucked, as shewn in *fig. 6*, and the point of the tool being applied to it, will cut a waved line. To do this more conveniently, the slider, *g*, is advanced to the work, by pressing it with the hand instead of the screw *i*; for, by lifting up a small spring catch, of which the tail is seen plainly at *3*, *fig. 6*, the slider is released from the nut of the screw *i*, which has no other attachment to the slider than by a tooth on this catch entering into a notch in the nut, and it is pressed into

the notch by a screw *l*. Now, by releasing the screw *l*, lifting up the catch *3*, and drawing back the slider, the tooth of the catch falls behind the nut of the screw, instead of being in the notch; it will, therefore, form a stop, to check the advance of the tool, though it allows it to be drawn back to clear the work, and also to be pushed up towards it by the hand, to cut the line, the stop regulating the depth of the line, as the hand can advance the slider no farther when it meets the nut.

In this manner, a waved line is engraved round the edge of it, such as is shewn in *fig. 9*, the breadth of the line being determined by the depth to which the point of the tool is regulated to penetrate, by turning the screw *i*. The outer line being thus finished, the tool is now withdrawn to clear the work, and the screw, *d*, of the great slider being turned a small quantity, the point of the tool is brought nearer to the centre of the work; here, by pushing up the tool, another line is described; then a third within the second, and so on, at equal distances, until they reach the centre: this makes a very pretty ornament, as in *fig. 9*. It should be observed, that as each line has the same number of waves, or indentations, they will necessarily grow very fine as they approach towards the centre; but at the same time as the deviation from the circular figure is equal in the smallest as well as the largest rings, it follows, that the curves of the waves of each ring, or line, will vary in a very gradual and pleasing manner, being slightly curved at the circumference, and more rapidly towards the centre. This pattern admits of great variety, by employing different rosettes, fine or coarse, concave or convex; but it will always have the waves included in straight lines directed to the centre. A very pretty variation is made by turning the rosette round upon the mandrel a very small quantity every time before a fresh line is described. For this purpose, the rosettes are not fixed fast upon the mandrel, but are fitted thereupon, so as to admit of turning round, being moved by a small screw at the end towards *H*. As an example of the use of this movement, *fig. 10*. is given, which consists of a row of twenty-four waves. In this, after drawing the exterior line, in the same manner as the former, when the slider is set for the second, the rosette is turned round upon the mandrel a quantity equal to one-fourth of a wave, or one-ninth-sixth part of the whole circle: the circle is now described, and its waves will not fall exactly within those of the former, but a little advanced therefrom. The next time a circle is to be drawn, the rosette is again shifted, and so on. As this is a quantity equal to one-fourth of the space between the waves, it is plain that at every fourth line the waves will fall in lines drawn towards the centre. Still this will not affect the appearance, which will be totally different from the former, (*fig. 9*.) and very superior to it. The concentric lines, in either of these patterns, are made exactly at equal distances, by means of the divisions before-mentioned, upon the slider *K*, or otherwise by divisions made upon a head, which is fitted upon the end of the screw *d*; and the rosettes are set exactly to the quantity they are intended to be turned round, by means of divisions made upon the edge of a circular plate, which is fixed fast upon the mandrel, towards the end *H*, and a line or mark upon the last rosette applies to it. The screw which effects the movement is supported in bearings upon this plate, and acts in the teeth of a wheel, fixed within the hollow of the last rosette. By this means, when the screw is turned round by a key, it causes all the rosettes to turn round together any quantity which the divisions on the circle indicate. On this principle, great varieties of patterns may be made, and they may be greatly diversified by shifting the rosettes alter-

ately in contrary directions: thus, after eight, twelve, or any other number of rings have been drawn, by gradually shifting them each time, as before described. By reversing the shifting movement to the opposite direction, a total change will be produced; and continuing in this manner for eight or twelve more circles, the rosettes are again to be advanced in the first-mentioned direction, and continued for eight or twelve. This method produces a curious effect, and admits of much variety in the patterns.

After having drawn a waved line, the rosette may be advanced half a division, and then another line drawn, without altering the slide-rest. By this means, the two waved lines will intersect each other, and make a number of loops like a chain of beads. A number of concentric lines of this sort, drawn upon a circle, is very handsome.

We have now shewn the principal distinctions of the patterns which can be described upon a flat surface; but it is evident, that from the number of the rosettes, a very numerous suit of curious combinations can be made. An elliptical and an excentric chuck are adapted to this machine, to screw on at T: a new field is thus opened, which is so extensive as to exercise constantly the taste and fancy of the operator, in producing new combinations, and renders the machine a source of the most interesting amusement. The elliptical and excentric chucks, when applied to a common lathe, will form a great many interesting patterns, but are vastly more extensive with the rose engine. Their construction will be described under TURNING. It is sufficient here to say, that by the elliptical chuck, the waved lines may be drawn in ellipses, instead of circles; and by the excentric, several small waved circles, or ellipses, can be arranged round the circumference of a larger circle, and their intersections produce a very pretty effect.

Another species of rose-turning is performed upon the surface of a cylinder, globe, or cone; whereas that which we have described is only upon the flat surface of a circular piece, or end of the cylinder. To ornament the surface of the cylinder, the slide-rest is turned round one-fourth of a circle, as before described, for forming the cylinder; so that the long slider becomes parallel to the mandrel. In this way the whole surface of the cylinder may be waved; but great care must be taken to advance the tool very gradually, because it will not cut so readily as when turning circular work. By dividing the length of the cylinder into small equal portions, and by shifting the rosettes every time one of these is finished, the waves may be made to follow each other in a spiral direction round the cylinder; or, by a proper rosette used in this manner, very elegant patterns of basket-work may be formed.

There is another movement of the rose lathe, which we have not yet described: this is called the pumping. It is principally used for describing waved lines upon the surface of a cylinder; that is, the surface is left cylindrical, but the lines are waved in the direction of the length of the cylinder, or alternately towards its ends. This is effected by making the mandrel move end-ways in its bearings: for which purpose, the necks upon which it turns are made exactly cylindrical, and fitted very correctly to steel collars, which are fixed into the standards, G, H. It has, therefore, liberty to slide end-ways in its collars, when the pumping motion is required. This is given by rosettes waved upon the edge or side, and acting against the side of a piece of steel, such as *n*, *fig. 7*. A spring, *p*, *fig. 6*, is fixed at the end of the frame, and acts against the shoulder of the mandrel, to force it end-ways, and keep the rosette always in contact with the piece of steel. The rosettes, M, are cut in a waved manner upon their sides, as well as upon

their circumferences; and thus a variety of pumping rosettes are obtained. By this means, curious waving lines may be drawn round a cylinder; or, if the motions first described are used in combination with the pumping, the surface of the cylinder may be waved, at the same time that waved lines are drawn upon it. In this case, the two rosettes employed must have the same number of waves. When the pumping motion is used upon face or flat work, such as is shown in *fig. 6*, it produces very agreeable effects, by rendering the waves of the line, which the tool cuts, alternately deeper and shallower, so as to give fine and strong strokes alternately, in the manner of fine writing: or, if the tool is not set so deep, they will only be cut on one side of the wave, and diminishing gradually, will not be seen on the other, and thus produce a number of new patterns; as the waved lines will consist of detached strokes, cut fine at each end, and deep in the middle.

Many patterns may be cut very expeditiously in the rose engine by means of screw tools: these tools are formed like a broad chisel, but the edge is cut with notches, so as to present a number of points instead of one continued edge. These points are very exactly equidistant, being intended to cut screws; and therefore the teeth are of the proper figure to form the threads thereof. By a tool of this kind six or eight lines may be cut at one operation, instead of the trouble of altering the slide-rest, and cutting each separately; and there will be a greater certainty of cutting them all to the same depth, and exactly equidistant. The mode of cutting screws by this tool is called cutting flying, and is thus performed in the rose, or in any common lathe, without a slide-rest. The intended screw being turned cylindrical, the points of the tool are applied to its surface, so that they will cut, and the tool is regularly advanced up towards the mandrel as it turns round: its teeth will, therefore, instead of describing circles, trace the spirals of a screw on the work; and if the advancement is timed so exactly that in one revolution the tool is advanced the exact quantity of a space between two adjacent teeth, then the second tooth will, at the end of a revolution, fall into the spiral cut by the first tooth, and one complete spiral being thus obtained, it guides the whole tool, by means of the second tooth, regularly along, the first tooth continuing to cut the spiral forwards till a third tooth lays hold, then a fourth, and so on, till the required length of a screw is cut. The trace of a screw being thus made, the tool is pressed deeper, till the threads are fully formed, the turner taking care, every time, that the end-tooth of the tool gets to the end of the screw, to disengage it, and draw it back, for as it could not advance any further than the shoulder, it would spoil all the threads by cutting them to circular rings.

This method requires great habit and dexterity to give the motion so exactly that it will cause the teeth to fall properly into the spirals cut by their predecessors, and that without any sudden advance at the place, for the screw would then be what is called drunken, that is, its threads would be more inclined at one part of its revolution than at another, and such a screw can never be fitted exactly with its fellow. The habit of cutting screws accurately with the screw-tool, can only be acquired by practice and experience, the only precaution which is taken being to get the lathe-wheel into a regular motion, and at such a rate as has been found, by experience, will be proper for the size of the thread intended to be cut. The rose engine before us has a very complete apparatus for cutting screws, which deserves a particular description. A tube is fitted on the end of the mandrel at *a*, its circumference being cut with a spiral, or screw-thread of the degree of fineness required: this is called the regulator screw.

H is a slider, fitted to the standard H, and moved by a screw: *r* is a wheel fixed to this slider, and having several half-circle cavities cut in it, which embrace the screw, as shewn in *fig. 10*: each cavity or socket has a thread in it, corresponding with the regulator screw. The mandrel being made, as before-mentioned, with cylindrical collars at each end, is at liberty to slide endways by the movement of the regulator, when the screw H draws up the socket *r*; therefore, every thing being prepared for cutting the thread, the screw H is turned; this raises up the slider, and socket *r*, to touch the regulator; the tool is then applied by the slide-rest, and the lathe being put in motion, the mandrel will move along endways, and also the work with it, so that the tool will cut a screw, although it is held fast by the rest. In this case the screw may be cut by a single pointed tool, but it will be better to use a screw tool which is of exactly the same thread as the regulator. The turner should be provided with a variety of sets of screw tools, and as many regulators, *o*, corresponding to them, which are made like a tube, and fitted on the mandrel, being held by a nut. The socket *r*, which is made like a wheel, *fig. 10*, can be turned round on its centre, and has

six different half-circle notches cut in it, each adapted to a particular regulator; therefore, by turning this wheel, *r*, any of the notches can be applied to the regulator *o*, when the slider is raised up by the screw H. This screw regulator may be sometimes used to advantage when ornamenting the circumference of a cylinder of wood or ivory, as contiguous circles, or waved lines, may then be cut in a spiral direction, without moving the slide-rest to cut each one separately.

Another part of the rose engine is for the purpose of turning swash work; this is circular work, but the mouldings or other lines traced round the cylinder are inclined to the axis. An instance is seen in the balustrades of old-fashioned stair-cases, where the mouldings are made to suit the inclination of the stairs. To turn this kind of work, a steel circle, or hoop, V, is fitted on the end rosette of the mandrel, so that it can be inclined from the perpendicular thereto at pleasure: by this means it forms a guide for the pumping motion, which will so regulate it as to turn any work of this kind, *viz.* with the mouldings, or other ornaments, arranged in lines round the cylinder, but these lines will incline to the axis of the cylinder instead of being perpendicular to it.

Rotherham

ROTHERAM, in *Geography*, a market-town and parish in the upper division of the wapentake of Strafford and Tickhill, West-Riding of Yorkshire, England, is situated near the confluence of the rivers Rother and Don, at the distance of 45 miles S. by W. from the city of York, and 160 miles N.N.W. from London. It is described by Leland as "a meatly large town, with a faire collegiate chireh," which was founded by Thomas Scott, archbishop of York, and a native of Rotheram, in 1481, for a provost, five priests, a school-master in song, and six choristers, also a school-master in grammar, and another in writing. This establishment was dissolved by king Henry VIII. Camden calls Rotheram "a large footy market town," and not unaptly, for even at the present day it is far from meriting the appellation of handsome or agreeable. The streets are narrow and irregular; and the houses, which are mostly constructed of stone, have a dull and dingy appearance. A considerable trade in coals and other articles is carried on here, by means of the river Don. The market day for corn, cattle, and butcher's meat is on Monday, weekly; and on every alternate Monday is a fair for fat cattle, sheep, and pigs; there are also two annual fairs, on Whit Monday, and the first day of December. Both markets and fairs are well attended; indeed Rotheram is one of the two greatest marts in Yorkshire for fat cattle and sheep. The chief public buildings are the town-hall, the parish-church, and two meeting-houses, one for Independents and another for Methodists. The church, according to Burton, in his "*Monasticon Eboracense*," was erected in the reign of Edward IV. It is a handsome and

spacious edifice, in the early pointed style, and consists of a nave, with two side aisles, a chancel, and a tower at the west end. Annexed to the church is a school-house, for the education of thirty poor children of the parish of Rotheram. The clergyman for the time is governor, and has the nomination of the children; but the trustees of the founder, Thomas Hollis, of London, esq. appoint the master. This institution is managed under very excellent regulations, a copy of which is delivered to the parents of all children admitted to its benefits. In this town is likewise an academical institution, or college, for the education of Protestant dissenters. It is called "The Rotheram Independent Academy," because more immediately connected with the class of religionists called Independents. It was first opened in November, 1795, under the superintendence of the Rev. Dr. Williams, who presided as divinity tutor, and is designed for the education of young men proposing to become Independent clergymen. This academy is supported by voluntary contributions. The building appropriated to it was erected by the late Samuel Walker, esq. and is calculated for the convenient accommodation of sixteen students. The library contains above 1200 volumes, chiefly presented by patrons of the institution; and there is likewise a tolerable collection of philosophical apparatus. The term of study is four years, but the managers have a discretionary power to prolong it if they think proper.

According to the parliamentary returns of 1811, the town of Rotheram alone contained 731 houses, and 2950 inhabitants; and the rest of the parish, including the town-

ships of Brinsworth, Catcliffe, Dalton, Orgreave, and Tinsley, 209 houses, and 986 inhabitants.

On the opposite side of the river from Rotherham is the township, or village, of Maxborough, where very extensive iron-works are carried on by Messrs. Walker. At these works cannon of the largest calibre are manufactured, as are also almost every kind of cast-iron articles, with many of wrought-iron, such as bar, sheet, slit, or rod iron. Tin plates, and steel of every description, are likewise made here in great quantities; and the iron bridges at Sunderland and Yarm were cast at these founderies. The coal, and the iron-stone for the blast-furnaces, are chiefly supplied from the mines on the estates of the earl of Essingham, and those of earl Fitzwilliam. These works were commenced, in 1746, by Mr. Samuel Walker, and his brothers Aaron and Jonathan, and have ever since been progressively increasing in extent and importance. In the Methodist meeting-house is a monument in memory of Mr. S. Walker; the epitaph was composed by the celebrated poet, the Rev. William Mason, who was one of his most intimate friends.

The environs of Rotherham are agreeable and picturesque. On an eminence to the eastward of the town stands an elegant mansion, belonging to the Walker family, which, in point of situation, can scarcely be excelled. Aldwark-Hall, the seat of J. S. Foljambe, esq. situated at the distance of four miles from Rotherham, is also remarkable for its fine situation. Near it is the village of Wickersley, noted for its

manufacture of grindstones, of which about 5000, of various sizes, are stated to be formed annually, and sent to Sheffield. The other principal seats in the neighbourhood of Rotherham, besides those mentioned, are Thundercliffe Grange, the seat of the earl of Essingham, and Wentworth House, the princely residence of earl Fitzwilliam. The latter house consists of a centre and two wings, extending about 600 feet in length. Many of the apartments are most superb, especially the hall and gallery, the latter of which is supported by beautiful Ionic columns, having intervening niches filled with marble statues. Here, and in other parts of the house, are likewise many paintings; and among others the famous picture of lord Strafford and his secretary. Some fine antiques are preserved in a room called the museum. Wentworth-park comprises upwards of 1500 acres of ground, beautifully diversified with wood, water, and lawn, and is enriched by several ornamental buildings. Among these is a most magnificent mausoleum, erected by the present earl Fitzwilliam, in honour of his uncle, the late marquis of Rockingham. It is constructed of a very fine free-stone, and consists of three divisions; the first is a square Doric basement; the second of the same form, but of the Ionic order; and the third presents a cupola, supported by twelve columns of the same character. Within is an apartment rising into a dome, which rests upon eight pillars, encircling a white marble statue of the marquis in his robes of state, executed by Mr. Nollekens. *Beauties of England and Wales*, vol. xvi. by J. Bigland.

Rum

RUM, a species of vinous spirit, drawn by distillation from sugar-canes.

The word **rum** is the name it bears among the native Americans.

Rum is very hot and inflammable, and is in the same use among the natives of the sugar-countries, as brandy among the French.

Rum differs from what we simply call sugar-spirit, in that it contains more of the natural flavour or essential oil of the sugar-cane; a great deal of raw juice, and parts of the cane itself, being often fermented in the liquor, or solution of which the rum is prepared.

The unctuous or oily flavour of rum is often supposed to proceed from the large quantity of fat used in boiling the sugar; which fat, indeed, of course, will usually give a stinking flavour to the spirit in our distillation of the sugar liquor, or wash, from our refining sugar-houses; but this is nothing like the flavour of the rum, which is really the effect of the natural flavour of the cane. The method of making rum is this:

When a sufficient stock of the materials is got together, they add water to them, and ferment them in the common method, though the fermentation is always carried on very slowly at first; because at the beginning of the season for making rum in the islands, they want yeast, or some other ferment, to make it work; but by degrees, after this, they procure a sufficient quantity of the ferment, which rises up as a head to the liquor in the operation, and thus they are able afterwards to ferment and make their rum with a great deal of expedition, and in large quantities.

When the wash is fully fermented, or to a due degree of acidity, the distillation is carried on in the common way, and the spirit is made up proof; though sometimes it is reduced to a much greater strength, nearly approaching to that of alcohol or spirit of wine, and is then called double-distilled rum. It might be easy to rectify the spirit, and bring it to much greater purity than we usually find it to be of; for it brings over in the distillation a very large quantity of the oil; and this is often so disagreeable, that the rum must be suffered to lie by a long time to mellow before it can be used; whereas, if well rectified, it would grow mellow much sooner, and would have a much less potent flavour.

The best state to keep rum in, both for exportation and other uses, is doubtless that of alcohol, or rectified spirit. In this manner it would be transparent in one-half the bulk it usually is, and might be let down to the common proof strength with water when necessary. For the common use of making punch, it would likewise serve much better in the state of alcohol; as the taste would be cleaner, and the strength might always be regulated to a much greater exactness than in the ordinary way.

The only use to which it would not serve so well in this state, would be the common practice of adulteration among our distillers; for when they want to mix a large portion of cheaper spirit with the rum, their business is to have it of the proof strength, and as full of the flavouring-oil as they can, that it may drown the flavour of the spirits they mix with it, and extend its own. If the business of rectifying rum was more nicely managed, it seems a very practicable scheme to throw out so much of the oil, as to have it in the fine light state of a clear spirit, but lightly impregnated with it; in this case it would very nearly resemble arrac, as is proved by the mixing a very small quantity of it with the tasteless spirit, in which case the whole bears a very near resemblance to arrac in flavour.

Rum is usually very much adulterated in England; some are so barefaced as to do it with malt-spirit; but when it is done with molasses-spirit, the tastes of both are so nearly allied, that it is not easily discovered. The best method of judging of it is by setting fire to a little of it; and, when it has burnt away all the inflammable part, examining the

phlegm both by the taste and smell. *Shaw's Essay on Distillery.*

Mr. B. Edwards, in his "History of the West Indies," vol. ii. has given the following account of the process for extracting rum from the sugar-cane, or from the very dregs and feculencies of the plant, by fermentation and distillation. He commences his account with observing, that the still-houses on the sugar-plantations in the British West Indies, vary greatly in point of size and expence, according to the fancy of the proprietor, or the magnitude of the property. In general, however, they are built in a substantial manner of stone, and are commonly equal to the boiling and curing-houses together. (See SUGAR.) For a plantation making, *communibus annis*, 200 hogheads of sugar of 1600 weight, our author conceives, that two copper stills, the one of 1200, and the other of 600 gallons, wine measure, with proportionate pewter worms, are sufficient. The size of the tanks (or tubs) for containing the cold water in which the worms are immersed, must depend upon circumstances; if the advantage can be obtained of a running stream, the water may be kept abundantly cool in a vessel barely large enough to contain the worm. If the plantation has no other dependance than pond-water, a stone tank is much superior to a tub, as being longer in heating, and if it can be made to contain from twenty to thirty-thousand gallons, the worms of both the stills may be placed in the same body of water, and kept cool enough for condensing the spirit, by occasional supplies of fresh water.

For working these stills and worms, it is necessary to provide, first, a dunder-cistern, of at least three thousand gallons; secondly, a cistern for the scummings; and lastly, twelve fermenting vats, or cisterns, each of them of the contents of the largest still, *viz.* 1200 gallons. In Jamaica, cisterns are made of plank, fixed in clay; and are universally preferred to vats or moveable vessels, for the purpose of fermenting. They are not so easily affected by the changes of the weather, nor so liable to leak as vats, and they last much longer. But in the British distilleries, fermenting cisterns, it is said, are unknown. To complete the apparatus, it is necessary to add two or more copper pumps for conveying the liquor from the cisterns, and pumping up the dunder, and also butts or other vessels for securing the spirit when obtained; and it is usual to build a rum-store adjoining the still-house.

The ingredients or materials for the process consist of molasses, or treacle drained from the sugar; scummings of the hot cane-juice, from the boiling-house, or sometimes raw-cane liquor, from canes expressed for the purpose; lees, or, as it is called in Jamaica, "dunder," from the Spanish *redunder*, the same as *redundans* in Latin; and water. Dunder, in the making of rum, serves the purpose of yeast in the fermentation of flour. It is the lees or feculencies of former distillations; and some planters preserve it for use from one crop to another; but this is said to be a bad practice. Some fermented liquor, composed of sweets and water alone, ought to be distilled in the first instance, that fresh dunder may be obtained. This is a dissolvent menstruum, and occasions the sweets with which it is combined, whether molasses or scummings, to yield a far greater proportion of spirit than can be obtained without its assistance. The water which is added acts in some degree in the same manner by dilution.

In the Windward islands, the process, we are told, is conducted as follows: the ingredients, *viz.* scummings, one-third; lees or dunder, one-third, and one-third of water, are well mixed in the fermenting cisterns, and when they are pretty cool, the fermentation will rise, in twenty-four hours,

to a proper height for admitting the first charge of melasses, of which six gallons for every hundred gallons of the fermenting liquor, is the general proportion to be given at twice; viz. three *per cent.* at the first charge, and the other seven *per cent.* a day or two afterwards, when the liquor is in a high state of fermentation; the heat of which, however, should not, in general, be suffered to exceed from 90° to 94° Fahrenheit. The infusion of hot water will raise, and of cold water abate the fermentation. The quantity of melasses above-mentioned, added to a third of scummings, gives 11½ *per cent.* of sweets, six gallons of scummings being reckoned equal to one gallon of melasses. When the fermentation falls by easy degrees from the fifth to the seventh or eighth day, so as then to become fine, and throw up slowly a few clear beads or air-globules, it is ripe for distillation; though when the liquor is first set at the beginning of the crop (the house being cold, and the cisterns not saturated) it will not be fit for distillation under ten or twelve days. When this is the case, at a longer or shorter period, the liquor or wash being conveyed into the largest still, which must not be filled higher than within eight or ten inches of the brim, lest the head should fly, a steady and regular fire must be kept up until it boils, after which a little fuel will serve. In about two hours the vapour or spirit, being condensed by the ambient fluid, will force its way through the worm in the shape of a stream, as clear and transparent as crystal, and it is suffered to run until it is no longer inflammable. The spirit thus obtained is known by the appellation of "low wines." To make it rum of the Jamaica proof, it undergoes a second distillation. Between the practice of the Jamaica distillers, and that of those of the Windward islands, there is some little variation in the first process. This consists chiefly in the more copious use of dunder. As dunder serves to dissolve the tenacity of the saccharine matter, it should be proportioned, not only to the quantity, but also to the nature of the sweets. If the sweets in the fermenting cistern consist of melasses alone, which is generally the case after the business of sugar-boiling is finished, when no scummings are to be had, a greater proportion of dunder is necessary; because melasses are a body of greater tenacity than cane-liquor, and are rendered so viscous and indurated by the action of fire, as to be unfit for fermentation without the most powerful saline and acid stimulants. For the same reason, at the beginning of the

crop, when no melasses can be had, and the sweets consist of cane-juice or scummings alone, very little dunder is necessary. In such case twenty *per cent.* at the utmost will be sufficient. Dunder, in a large quantity, injures the flavour, though it may increase the quantity of the spirit. Dr. Shaw says, that the English distillers add many things to the fermenting liquor or wash, in order to augment the vinosity of the spirit, or to give it a particular flavour. He observes, that a little tartar, nitre, or common salt, is sometimes thrown in at the beginning of the operation, or in their stead a little of the vegetable or finer mineral acid. These are thought to be of great use in the fermenting of solutions of treacle, honey, and similar sweet and rich vegetable juices, which contain a small proportion of acid. A similar practice is said to prevail among the distillers in St. Christopher's, some of which consider an addition of sea-water to the fermenting liquor as a real and great improvement. Shaw recommends the juice of Seville oranges, lemons, and tamarinds, or other very acid fruits, and, above all other things, an aqueous solution of tartar; but Mr. Edwards is of opinion, that dunder alone answers every purpose. Dr. Shaw also recommends to the distiller to introduce into the fermenting cistern a few gallons of the rectified spirit, which, he says, will revert, with a large addition, to the quantity of spirit that would otherwise have arisen from the distillation. It is suggested by Mr. Edwards, that a small quantity of vegetable ashes, thrown into the rum-still, will be found serviceable. The alkaline salts are supposed to attenuate the spirit, and keep back the gross and fetid oil, which the distillers call the "faints," but if too freely used, they will also keep back a proportion of the fine essential oil, on which the flavour of the rum wholly depends. After all, the most important object of attention in making good rum is probably "cleanliness;" for all adventitious or foreign substances destroy or change the peculiar flavour of the spirit. It should, indeed, be an invariable practice with the manager or distiller to take care that the cisterns are scalded, and even cleaned with strong lime-water, every time when they are used; not merely on account of the rum, but because it has often happened that the vapour of a foul cistern has instantly killed the first person that has entered it without due precaution.

The following improved method of conducting the process, or of compounding the several ingredients, is very general in Jamaica, viz.

Dunder one half, or		50 gallons	
Sweets 12 <i>per cent.</i>	-	6 gallons	
		36 gallons	
		(equal to six gallons	42 gallons.
		more of melasses)	
Water	-	8 gallons	
		<hr/>	
		100	

Of this mixture, or "wash," as it is sometimes called, 1200 gallons ought to produce 300 gallons of low-wines; and the still may be twice charged or drawn off in one day. The method of adding all the melasses at once, which is done soon after the fermentation commences, renders the process safe and expeditious; whereas by charging the melasses at different times, the fermentation is checked, and the process delayed.

The low-wines obtained in the manner above described, are drawn off into a butt or vessel, and, as opportunity serves, are conveyed into the second still of 600 gallons, to undergo a further distillation. The steam begins to run in about an hour and a half, and will give, in the course of

the day, 220 gallons, or two puncheons, of oil-proof rum, i. e. of spirit in which olive oil will sink; and thus the manufacture, if so it may be called, is complete. There will remain in the still a considerable quantity of weaker spirit, commonly about 70 gallons, which is returned to the low-wine butt. Thus 220 gallons of proof-rum are made, in fact, from 530 gallons of low-wines, or about 113 of rum from 1200 of wash. By this process the Jamaica distiller may fill weekly, working only by day-light (a necessary precaution in this employment), and at a small expence of labour and fuel, twelve puncheons of rum, containing each 110 gallons of the Jamaica standard. The proportion of the whole rum to the crop of sugar, is commonly estimated

in Jamaica as three to four. Thus a plantation, such as we have above described, is supposed to supply annually 150 puncheons of rum of 110 gallons each, or 82 gallons of Jamaica proof to each hog-head of sugar; and this quantity is sometimes fairly made from canes planted in rich and moist lands; but on a general estimate, Mr. Edwards thinks this to be too great an allowance; and that 200 gallons of rum to three hog-heads of sugar, which is in the proportion of about two-thirds rum to the crop of sugar, is nearer the truth. The following statement warrants the above conclusion. The general supply of scummings to the liquor-house is seven gallons out of every 100 gallons of cane-liquor. Supposing, therefore, that 2000 gallons of cane-juice are required for each hog-head of sugar of 16 cwt., the scummings, on a plantation making 200 hog-heads *per annum*, will be 28,000 gallons, equal to 4666 gallons of melasses.

Add the melasses from the curing-house, which, if the sugar is of a good quality, will seldom exceed 60 gallons *per* hog-head } 12,000

Total of sweets 16,666 gallons.

This quantity, distilled at or after the rate of 12 *per cent.* sweets in the fermenting cistern, will give 34,720 gallons of low-wines, which ought to produce 14,412 gallons of good proof rum, or 131 puncheons of 110 gallons each. When a greater proportion than this is made, either the sugar discharges an unusual quantity of melasses, or the boiling-house is defrauded of the cane-liquor by improper scumming; which latter circumstance frequently happens.

It is the practice of late, we are told, with many planters, to raise the proof of rum: thus gaining in strength of spirit what is lost in quantity: and some managers make it a rule to return the scummings to the clarifiers, instead of sending them to the still-house. This last-mentioned practice reduces the crop of rum more than one-third; but is supposed to yield in sugar more than is lost in rum: and if the price of sugar is very high, and that of rum very low, it may be prudent to adopt this method.

For the duty, &c. on rum, see *Foreign SPIRITS*.

RUM, in *Geography*, a town of Tonquin, on the coast. N. lat. 19° 35'. E. long. 105° 18'.—Also, a river of America, which runs into the Mississippi, N. lat. 45°. W. long. 93° 48'.

RUM, one of the Hebrides, or Western islands of Scotland, is situated to the westward of the isle of Skye, and is comprised, politically, in the parish of Small-Isles, and in the county of Argyle. It derived its name from the Gaelic, *Rhum*, signifying extent, in allusion to its being the largest island in the parish to which it belongs. It is computed to measure eight miles in length, and nearly the same in breadth; and to contain about 22,000 square acres. Rum is in

general rugged, mountainous, and barren, and more adapted for pasturage than for agriculture. Horses are reared in this island for sale, and though diminutive in size, are remarkably high mettled and hardy. Here are likewise reared a considerable number of sheep, which are the best stock with which a mountainous country, like Rum, can be supplied. The general breed is a small white-faced sheep, which is much praised, both for the delicate flavour of its flesh, and for the excellence of its wool. This island formerly abounded with deer; but that animal is now totally extirpated, owing to the copse wood, which served as a cover to their fawn, having been destroyed. Before the use of fire-arms, the method adopted by the inhabitants to kill deer was so singular as to deserve notice. On each side of a glen formed by two mountains, stone dykes were constructed at a considerable height up the hills, and extended from thence to the lower part of the valley, always drawing nearer to each other, till they approached within three or four feet. This narrow pass opened into a circular space, inclosed by a wall of sufficient height to restrain the deer, which were pursued hither and destroyed. The remains of one of these ancient deer-traps are still to be traced. Birds of prey are numerous in Rum; and there are likewise a few grouse, pigeons, terrapants, and wild ducks, besides those birds which frequent the island only at stated seasons of the year. The air of Rum, from its proximity to the western ocean, is moist, and the weather extremely rainy. The only harbour here is Loch-Serfort, which penetrates a considerable way into the island, on its eastern coast. It is spacious, its ground good, and its depth of water from five to seven fathoms. Near the head, on the south side of this harbour, a pier has been lately erected. The general appearance of Rum is, that the land slopes towards the east; but on the west presents precipices of a tremendous height. At the base of the hill Sgormor are found abundance of agates, of that species called by Cronstedt "*Achates chalcodonitans*," improperly white cornelians. Here are several remarkable strata; such as grey quartz; a mixture of quartz and basalt; a black stone spotted with white, like porphyry, but with the appearance of lava; fine grit or free-stone; and the cinereous indurated bole of Cronstedt. There being no mill in this island, the corn is "gradanned," or burnt out of the ear, instead of being thrashed. This is performed in two ways: first by cutting off the ears and drying them in a kiln, and then setting fire to them on the floor, and picking out the grains; and secondly, by burning the sheaf entire, which is a most ruinous practice, as it destroys both thatch and manure. Gradanned corn is conjectured to have been the parched corn of holy writ.

Rum not being a parish of itself, its population is not stated in the parliamentary returns; but it is estimated to contain about 500 inhabitants. The Statistical Account of Scotland, by Sir John Sinclair, bart. 8vo. vol. xvii. 1796. Beauties of Scotland, vol. v. 8vo. 1808. Carlisle's Topographical Dictionary, 4to. 1813.

Saccharometer

SACCHAROMETER, in the *Arts*, an instrument for ascertaining the value of worts, and the strength of different kinds of malt-liquor. The name signifies a measurer of sweetness, and the instrument seems to depend on the following principles. The water employed by the brewer becomes more dense, that is, of a greater specific gravity, by the addition of materials extracted by, and dissolved in it, and thence, in fact, incorporated with it: the operation of boiling, and its evaporation in the subsequent cooling, still augment the specific gravity, so that when it is submitted to the action of fermentation, it is found to be denser than at any other period. In passing through this natural operation, a remarkable operation takes place. The fluid, as soon as it begins to ferment, begins also to diminish in its density, and as the fermentation is more or less perfect, the fermentable matter, whose accession has been traced by the increase of density, becomes more or less attenuated, and a spirituous fluid, of less density than water, is produced; so that when the liquor is again in a state of rest, it is so much specifically lighter than it was before, as the action of fermentation has been capable of attenuating the liquid of its acquired density; and if the whole were affected in like manner, the liquor would become lighter, or of less specific gravity than water, because the quantity of spirit produced from the fermentable matter, and occupying its place, would diminish the density of the water in some sort of proportion to that in which the latter was increased. Such is the account given of the saccharometer, and the theory of its action. On this subject it has been asked if the saccharometer is an instrument which truly indicates the strength of malt-liquor; and are the constituents of malt always dissolved in the same proportions to each other? because unless this be

the case, there can be but little dependence placed upon it. To this it has been answered, by a very modern writer, that the saccharometer indicates correctly the specific gravity of the wort before it begins to ferment. The value of the beer or ale, supposing the process properly conducted, always depends upon the strength, that is, the specific gravity, because the same substances are always taken up from good malt; and the real value of beer, to say nothing of the market price, is always proportional to the specific gravity of the wort. See **HYDROMETER**.

Another writer on the subject (see Dr. Thompson's *Annals*) observes, that according to the common acceptance of the word *strength*, in beer or ale, the saccharometer foretels it sufficiently near the truth, for *similar* processes in the *same* brewhouse, but it is by no means a sure guide for any dissimilarity in the mode of brewing, or of drawing the extract; for then the constituents of malt are *not* often dissolved in the same proportion to each other, and in all cases the extracts are superior in value according to their priority. For, let the first, from the same parcel of malt, be reduced to the specific gravity of the last, and an equal quantity of each will give a beer very different in quality.

The quantity of alcohol increases during fermentation, as the specific gravity of the fermenting fluid diminishes, but in what ratio no correct experiments have as yet ascertained. The term designated *strength*, in malt liquors, depends, however, on many inexplicable circumstances. It is nevertheless certain that the common saccharometer does not give the quantity of solid matter contained in a given quantity of wort, it shews merely the difference of weight between that and the same quantity of water.

Sail-making

SAIL-Making. By act of parliament for encouraging the use and consumption of the manufacture of British fail-cloth, every ship or vessel which shall be built in Great Britain, and every ship or vessel which shall be built in any of his majesty's plantations in America, shall, upon her first setting out to sea, have or be furnished with one full and complete suit of sails, made up of fail-cloth manufactured in Great Britain; and in case such ship shall not, on her first setting out, be so fitted out and furnished, that then, and for every such neglect and default, the master of such ship shall forfeit the sum of fifty pounds.

It is likewise enacted, that all fail-cloth made in Great Britain shall be manufactured in the manner, and according

to the directions hereafter mentioned, viz. every piece or bolt of British fail-cloth, that shall be twenty-four inches in breadth, and thirty-eight yards in length, shall weigh according to the number and weights here mentioned: viz. N^o 1, 44 pounds each bolt; N^o 2, 41; N^o 3, 38; N^o 4, 35; N^o 5, 32; N^o 6, 29; N^o 7, 24; N^o 8, 21; N^o 9, 18; and N^o 10, 15 pounds each bolt.

And in case any piece or bolt of either such respective numbers or sorts of British fail-cloth shall be made of a different breadth or length than before-mentioned, such piece or bolt of British fail-cloth shall be increased or diminished in weight, in proportion to the difference in length or breadth, and shall be marked or stamped with such number

as shall be agreeable to the weight; and the warp or chain of every piece or bolt of the first six numbers of such British fail-cloth, shall be wholly wrought and made of double yarn, and shall contain in every piece or bolt of twenty-four inches in breadth, at least 560 double threads of yarn; and in every piece of such fail-cloth, that shall be thirty inches in breadth, at least 700 double threads of yarn; and in every bolt of such fail-cloth, that shall be of any other breadth than as aforesaid, a certain number or quantity of double threads of yarn, in proportion to the number of double threads of yarn expressed to be contained in the breadth, as aforesaid; and the warp and shoot-yarn, which shall be wrought in every piece or bolt of the first four numbers of such fail-cloth, shall be made of long flax, without any mixture of short or bar flax; or of long flax, of Italian hemp, or Braak hemp; and all the flax and hemp used in making the warp and shoot-yarn of such fail-cloth, of the aforesaid four first numbers, shall be of a strong staple, fresh, sound, and good in its kind, and well dressed, and the yarn well cleansed, even spun, and well twisted; and all the shoot-yarn of each piece of fail-cloth of the four first numbers, shall be full as strong as the warp-yarn, and close struck with four shoots of treble threads at the distance of every two feet, or thereabouts; and both the warp and shoot-yarn shall be as strong as the warp and shoot-yarn that are usually wrought in the fail-cloth of those four first numbers that are made for and used in his majesty's navy; and no flax-yarn used in any British fail-cloth shall be whitened with lime, on forfeiture of sixpence per yard, for every yard that shall be so whitened, made, fold, or worked up into new fails in Great Britain, any way essentially different, lighter, or inferior in strength and goodness to any of the aforesaid directions or restrictions.

Every fail-maker, or other person who shall make or work up fail-cloth into fails or tarpaulins, shall cause this act, or an abstract thereof, to be put up or affixed, there to continue, in some public part of the loft, shop, or workhouse, where his said trade is carried on, or his workmen employed, under the penalty of forty shillings.

The several acts relative to fail-cloth and fail-making are the act of the 7 & 8 W. III. c. 10. § 14. 9 & 10 W. III. c. 41. 9 Geo. II. c. 37. 19 Geo. II. c. 27. 33 Geo. III. c. 49.

The First Process in Sail-making

Is the cutting out the various fails cloth by cloth, the width being governed by the length of the yard, gaff, boom, or stay, to which they bend; the depth by the height of the mast. The width and depth being given, find the number of cloths the width requires, allowing for seams, slack-cloth for sewing on the bolt-rope, and tabling on the leeches; and in the depth allow for tabling on the head and foot. For fails cut square on the head and foot, with gores only on the leeches, as some topsails, &c. the cloths on the head, between the leeches, are cut square to the depth; and the gores on the leeches are found by dividing the depth of the fail by the number of cloths gored, which gives the length of each gore. The gore is set down from a square with the opposite selvage, and, the canvas being cut diagonally, the longest gored side of one cloth makes the shortest side of the next; consequently, the first gore being known, the rest are cut by it.

For the length of gores corresponding to the depth on the selvage, consult the following table, which shews the length of any gore by its depth, from one inch to six feet in depth on the selvage of canvas twenty-four inches wide.

Depth down the Selvage.		Length of the Gore.		Depth down the Selvage.		Length of the Gore.		Depth down the Selvage.		Length of the Gore.		Depth down the Selvage.		Length of the Gore.	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
0	1	2	0	2	1	2	10 $\frac{3}{4}$	4	1	4	7				
0	2	2	0 $\frac{1}{4}$	2	2	2	11 $\frac{1}{4}$	4	2	4	7 $\frac{1}{2}$				
0	3	2	0 $\frac{1}{2}$	2	3	3	0 $\frac{1}{2}$	4	3	4	8 $\frac{1}{2}$				
0	4	2	0 $\frac{3}{4}$	2	4	3	1	4	4	4	9 $\frac{1}{2}$				
0	5	2	0 $\frac{3}{4}$	2	5	3	1 $\frac{1}{4}$	4	5	4	10 $\frac{1}{2}$				
0	6	2	0 $\frac{7}{8}$	2	6	3	2 $\frac{1}{4}$	4	6	4	11 $\frac{1}{8}$				
0	7	2	0 $\frac{7}{8}$	2	7	3	3 $\frac{1}{4}$	4	7	5	0 $\frac{1}{4}$				
0	8	2	1 $\frac{1}{8}$	2	8	3	4 $\frac{1}{8}$	4	8	5	1 $\frac{1}{8}$				
0	9	2	1 $\frac{1}{4}$	2	9	3	5	4	9	5	2				
0	10	2	1 $\frac{3}{8}$	2	10	3	5 $\frac{7}{8}$	4	10	5	2 $\frac{3}{4}$				
0	11	2	2 $\frac{1}{4}$	2	11	3	6 $\frac{1}{4}$	4	11	5	3 $\frac{1}{4}$				
1	0	2	2 $\frac{1}{2}$	3	0	3	7 $\frac{1}{4}$	5	0	5	4 $\frac{1}{4}$				
1	1	2	3 $\frac{1}{4}$	3	1	3	8 $\frac{1}{4}$	5	1	5	5 $\frac{1}{4}$				
1	2	2	3 $\frac{1}{2}$	3	2	3	9 $\frac{1}{4}$	5	2	5	6 $\frac{1}{4}$				
1	3	2	4 $\frac{1}{4}$	3	3	3	10 $\frac{1}{4}$	5	3	5	7 $\frac{1}{4}$				
1	4	2	4 $\frac{1}{2}$	3	4	3	11 $\frac{1}{4}$	5	4	5	8 $\frac{1}{4}$				
1	5	2	5 $\frac{1}{4}$	3	5	4	0	5	5	5	9				
1	6	2	5 $\frac{3}{4}$	3	6	4	0 $\frac{7}{8}$	5	6	5	10				
1	7	2	6 $\frac{1}{4}$	3	7	4	1 $\frac{3}{4}$	5	7	5	11				
1	8	2	7	3	8	4	2 $\frac{1}{4}$	5	8	6	0				
1	9	2	7 $\frac{3}{4}$	3	9	4	3 $\frac{1}{4}$	5	9	6	1				
1	10	2	8 $\frac{1}{2}$	3	10	4	4 $\frac{1}{4}$	5	10	6	2				
1	11	2	9 $\frac{1}{4}$	3	11	4	5 $\frac{1}{4}$	5	11	6	3				
2	0	2	10	4	0	4	6 $\frac{1}{4}$	6	0	6	4				

In the leeches of topsails cut hollow, the upper gores are longer than the lower ones; and in fails cut with a roach-leech, the lower gores are longer than the upper ones. This can only be regulated by the judgment of the fail-maker, and care must be taken that the whole of the gores do not exceed the depth of the leech.

Sails gored with a sweep on the head or foot, or on both, have the depth of their gores marked on the selvage from the square of the given depth on each cloth, and are cut out as above; the longest selvage of one serving to measure the shortest selvage of the next, beginning with the first gored cloth next the middle in some fails, and the first cloth next the mast-leech in others.

For those gores that are irregular, and likewise the hollow leeches of topsails, &c. no strict rule can be given; but by drawing on paper the gored side of the fail, and delineating the breadth of every cloth by a convenient scale of equal parts of an inch to a foot, or, what would be better, laying-off the full size of the fail on the loft-floor, the length of every gore may be found with precision.

In the royal navy, mizen-topsails are cut with three-quarters of a yard hollow in the foot; but, in the merchant service, top and topgallant-fails are cut with more or less hollow in the foot. Flying jibs are cut with a roach-curve on the stay, and a three-inch gore in each cloth, shortening from the tack to the clue.

Lower studding-fails are cut with square leeches, and topmast and topgallant-mast-studding-fails with goring leeches.

For the cutting of all other fails, we refer to the particular description of each fail, which follows.

Tablings of all fails are to be of a proportionable breadth to the size of the fail. Those for the heads of main and fore-courses to be from 4 to 6 inches wide; for sprit-courses and mizens, drivers, and other boom-fails, 3 to 4 inches wide;

for top-fails, 3 to $4\frac{1}{2}$ inches; topgallant and sprit-topfails, 3 inches; royal fails, $2\frac{1}{2}$ inches; jib and other stay-fails, 3 to $4\frac{1}{2}$ inches, on the stay or hoist; and for studding-fails, 3 to 4 inches on the head.

Tablings on the foot and leeches of main and fore-courses to be from 3 to 5 inches broad; sprit-course and topfails, 3 inches; topgallant and sprit-topfails, $2\frac{1}{2}$ inches; royals, 2 inches; fore-leeches of mizen, driver, and other boom-fails, $3\frac{1}{2}$ to 4 inches; after-leech, 3 inches; and on the foot, 2 to 3 inches.

Tablings on the after-leech of jibs and other stayfails to be from 2 to 3 inches broad; and on the foot, 2 to $2\frac{1}{2}$ inches; on studding-fail-leeches, $1\frac{1}{2}$ to $2\frac{1}{2}$ inches; and on the foot, from 1 to 2 inches.

The length of reef and middle bands is governed by the width of the fail at their respective places: the leech-linings, buntline-cloths, top-linings, mast-cloths, and corner-pieces, are cut agreeable to the depth of the fail. Each cloth, and every article when cut, should be properly marked with charcoal, to prevent confusion or mistake.

Reef-bands.—Main and fore-courses have two reef-bands; the upper one is one-sixth of the depth of the fail from the head, and the lower band should be the same distance from the upper one, the ends going four inches under the leech-linings. The breadth one-third the breadth of the canvas.

Main and fore-topfails have four reef-bands, or three at least, from leech to leech, over the leech-linings; the upper one to be one-eighth of the depth of the fail from the head. They are the same distance asunder in the royal navy, but more in the merchant service. Mizen-topfails of 50-gun ships, and upwards, have three reefs; the upper one is one-eighth of the depth of the fail from the head, and the reefs are the same distance asunder. Mizen-topfails of lesser ships have two reefs one-seventh the depth of the fail from the head, and the same distance asunder. The reef-bands have each half a breadth of canvas. Main and main-top-studding-fails have each one reef, at one-eighth of the depth of the fail from the head.

The *middle band* is made of one breadth of canvas of the same number as the top-linings, and is put on half way between the lower reef and the foot.

Linings.—Main and fore-courses are lined on the leeches, from clue to earing, with one cloth. Main, fore, and mizen-topfails, have leech-linings made of one breadth of cloth, so cut as to be half a cloth broad at the head, and a cloth and a half broad at the foot; the cloth to be cut from half its breadth at one end, so as to taper to a point at the other.

Mizens are lined with one breadth of cloth from the clue five yards up the leech; they have also a nock-piece, and a peek-piece, one cut out of the other, so that each contains one yard.

The mast-lining is of two cloths, and extends from the foot of the fail to the lower reef, to receive the beat or chafe of the mast.

The top-lining of top-fails is of canvas N^o 6 or 7. The other linings of this and all other fails should be of the same quality as the fails to which they belong.

Lower stayfails, fore-top and main-top-stayfails, and flying jibs, have clue-pieces two yards long.

Square tack-stayfails have half a breadth of cloth at the fore-part; with a clue-piece containing two yards, and a peek-piece containing one yard.

Buntline-Cloths.—Main and fore-courses have four buntline-cloths, and all topfails two buntline-cloths, from the foot to the middle band, of one breadth of canvas.

Sails to have bonnets are cut out the whole depth of the

fail, bonnet included, allowing enough for the tablings on the foot of the fail, and head and foot of the bonnet. The bonnet is cut off after the fail is sewed together. If a drabber is required, it is allowed for in the cutting out the same, as in the bonnet.

The Second Process in Sail-making

Is the sewing of the various parts of a fail together; and, first, the

Seams.—Sails have a double flat seam, and should be sewed with the best English-made twine of three threads, spun 360 fathoms to the pound, and to have from 108 to 116 stitches in every yard in length.

The twine for sewing main, fore, mizen, and sprit-courses, topfails, and stayfails, in the royal navy, is waxed by hand with genuine bees-wax, mixed with one-sixth part of clear turpentine; and for small fails, in a mixture made of bees-wax 4 lb., hog's-lard 5 lb., and clear turpentine 1 lb. In the merchant service, the twine is dipped in tar, softened with a proper proportion of oil.

The breadth of the seams of courses, topfails, and other fails in the royal navy, to be as follow; viz. courses and topfails, for 50-gun ships and upwards, $1\frac{1}{2}$ inch; those under 50 guns, $1\frac{1}{4}$ inch, at head and foot; all other fails, one inch at head and foot.

In the merchant service, seams are sometimes made broader at the foot than at the head, being stronger.

Broad seams are not allowed to be made on courses in the royal navy, but goring leeches are adopted in lieu of them.

Driver boom-main-fails, and the fails of sloops, generally have the seams broader at the foot than at the head.

It is the erroneous practice of some fail-makers not to sew the seams any farther than where the edge is creased down for the tabling; but all fails should be sewed quite home to the end, and, when finished, should be well rubbed down with a rubber.

The seams of courses and topfails are stuck or stitched up, in the middle of the seams along the whole length, with double seaming-twine; and have from 68 to 72 stitches in a yard. In the merchant service, it is common to stick the seams with two rows of stitches when the fail is half worn, as they will then last till the fail is worn out.

Tablings of all fails to be sewed at the edge, with 68 to 72 stitches in a yard.

Reef-bands are each in breadth one-third of the breadth of the canvas for main and fore-courses. The reef-bands of main and fore-topfails are each of half a breadth of canvas, put on double; the first side is stuck twice, and the last turned over, so that the reef-holes may be worked upon the double part of the band; the ends go four inches under the leech-linings, which are seamed over the reef-bands. The reef-bands of topfails go over the linings from leech to leech, and are stuck with 68 to 72 stitches in a yard. Reef-bands should not be put on until the fail is sewed up, a contrary practice being very erroneous.

Middle bands have one breadth of canvas, and are first folded and rubbed down, to make a crease at one-third of the breadth; then tabled on the selvage, and stuck along the crease; then turned down, and tabled and stuck through both the double and single parts, with 68 to 72 stitches in a yard. They are likewise tabled or sewed over the ends of the buntline-cloths and top-linings.

It is the opinion of many, that middle bands should not be put on until the fail is half worn.

Linings.—All linings are seamed on, and are stuck, or stitched, in the middle, with 68 to 72 stitches in a yard.

Top-linings and mast-cloths are put on the aftside, and all other linings on the fore-side, of sails.

Holes.—Reef and head-holes are made by an instrument, called a pegging-awl, or a stabber, and are fenced round by stitching the edge to a small grommet, made with log or other line: when finished, they should be well stretched or rounded up by a pricker, or a marline-spike.

Sails have two holes in each cloth, at the heads and reefs of courses, top-sails, and other square sails; one hole in every yard in the stay of flying jibs; and one in every three-quarters of a yard in the stays of square, tack, and other stay-sails.

Reef and head-holes of large sails have grommets of 12-thread line, worked round with 18 to 21 stitches; smaller sails have grommets of 9-thread line, with 16 to 18 stitches, or as many as shall cover the line; and smaller holes in proportion.

The holes for marling the clues of sails, and the top-brims of top-sails, have grommets of log-line, and should have from 9 to 11 stitches: 12 holes are worked in each cloth.

Main-courses have marline-holes from the clue to the lower bowline-crinkle up the leech; and from the clue to the first buntline-crinkle on the foot. Fore-courses have marline-holes one-eighth of the depth of the sail up the leech, and from the clue to the first buntline-crinkle at the foot. Main and fore-top-sails have marline-holes three feet each way from the clue, and at the top-brims. Sprit-sails, mizen-top-sails, lower stay-sails, main and fore-top-stay-sails, and jibs, have marline-holes two feet each way from the clues. All other sails are sewed home to the clues.

Marline-holes of courses are at three-fourths of the depth of the tablings at the clues from the rope, and those of top-sails are at half the depth of the tablings at the clues and top-brim from the rope.

Bonnets have a head-tabling, to which a line that forms the lathings is sewed in bights, which are about six inches afunder; the leeches and foot are tabled, &c. similar to the foot of the sail the bonnet is attached to.

The Third Process in Sail-making

Is sewing on the bolt-rope, &c.

Bolt-ropes, before sewed, should be stoved in a stove by the heat of a flue, and not in a baker's oven, or in a stove-tub; and tarred with the best Stockholm tar; to be sewed on with good English-made twine of three threads, spun 200 fathoms to the pound. The twine in the royal navy is dipped in a composition made with bees-wax, four pounds; hog's-lard, five pounds; and clear turpentine, one pound; and in the merchant service, in tar softened with oil.

Bolt-ropes of courses, top-sails, and all other sails, should be neatly sewed on through every cunt-line of the rope; and to avoid stretching, the rope must be kept tightly twitted while sewing on, and care taken that neither too much nor too little slack is taken in: they are to be cross-stitched at the leeches every twelve inches in length, at every seam, and in the middle of every cloth at the foot, with three cross-stitches. Four cross-stitches should be taken at all beginnings and fastenings-off; the first stitch given twice, and the last three times. Small sails have two cross-stitches at every seam, and three at every fastening-off.

The number of threads required in the royal navy for sewing on the following sized bolt-ropes; viz. 6-inch, 10 ordinary and 2 extra; 5½ and 5½, 10 ordinary; 5½ and 5-inch, 8 ordinary and 2 extra; 4½ and 4½, 8 ordinary; 4½ and 4-inch, 6 ordinary and 2 extra; 3½ and 3½, 6 ordinary; 3½ and 3-inch, 4 ordinary and 2 extra; 2½ and 2½, 4 ordi-

nary; 2½ and 2-inch, 2 ordinary and 2 extra; 1½, 1½, 1½, and 1-inch, 2 threads ordinary.

Slack allowed in sewing on Bolt-ropes.—On main and fore-courses two inches slack-cloth should be allowed in the head and foot, and one inch and a half on the leeches, in every yard in length.

Mizen-courses have two inches slack in every yard in the fore-leech, but none in the after-leech or foot.

Sprit-sail-courses have no slack-cloth.

Top-sails are allowed three inches slack in every cloth in the foot, and one inch and a half in every yard in the leech, and two inches in every cloth left open in the top-brim.

Topgallant-sails have two inches slack in every cloth in the foot, and one inch in every yard in the leech.

Jibs have four inches slack in every yard on the stay, one inch in every cloth in the foot, and none on the leech.

Stay-sails have three inches slack in every yard on the stay, one inch in every cloth in the foot, but none on the leech.

Studding-sails have one inch and a half slack in every yard in goring-leeches, but no slack on square-leeches, and one inch in every cloth on the head and foot.

The clues and top-brims should be wormed while the bolt-rope is sewing on the sail, and before both parts are confined.

Clues.—Fourteen turns or twits of the strands in the length of the clue-rope are left at the lower corners of all sails for the clues, which are wormed with sizeable spun-yarn, parcelled, served, marled, and seized. The clue-ropes of main-courses extend, and are marled, from the clue to the lower bowline-crinkle up the leech, and to the first buntline-crinkle on the foot; on fore-courses one-eighth of the depth of the sail up the leech, and to the first buntline-crinkle on the foot; the clue-ropes of main and fore-top-sails extend three feet each way on the leech and foot: and sprit-sails, mizen-top-sails, lower stay-sails, main and fore-top-stay-sails, and jibs, have the clue-rope two feet each way from the clue.

Cringles.—Cringles should be made of the strands of new bolt-rope, half an inch smaller than the bolt-rope on the sail.

Earing-cringles are made of an additional length (of fourteen twits or turns) of the leech-rope left at the head of the sail, which, being turned back, forms the cringle, by splicing its end into the leech-rope and cross-stitching the whole of the splice; the first stitch to be given twice, and the last stitch three times.

Splices are made by opening the ends of two ropes, and placing the strands between each other: openings being made in the untwitted part of the rope nearest the end with a marline-spike, the strands are thrust through them; and the large ends are regularly tapered from the middle by cutting away some of the yarns every time they are thrust through. The small strands, as those of the foot or leech-rope, are stuck twice through the openings made in the large rope; and the large strands are stuck three times through the leech or foot-rope. The middle strand of the taper, being the longest, is stuck in last, and once more than the others. All splices are cross-stitched as far as they run.

Reef and reef-tackle pendant-cringles are stuck through holes made in the tablings, and the lower ends are put through the bolt-rope once more than the upper ends, being more liable to be drawn out.

The openings of buntline and bowline-cringles are at the distance of four turns or twits of the strands in the bolt-

rope afunder, and the ends are first stuck in an opening, made with a marline-spike, under two strands of the bolt-rope; then passing over the next, they are stuck under one strand; and again passing over another, they are finally stuck under the next. The ends of the buntline-cringles, next the service of the clues of courses, should be left long enough to be worked under the service, to meet or reach the ends of the clue-rope. See Plate I. fig. 26.

Rules for ascertaining the Quantity of Canvas contained in the different Sails.

Canvas 24 inches wide is used for the royal navy, and is certainly the strongest. Various widths of canvas are used in the merchant service, from 24 to 36 inches. The following rules are adapted equally to all widths, although the examples are calculated for canvas 24 inches wide.

Rule 1.—To find the quantity of canvas in main and fore-courses; topsails; topgallant-sails; royals; topmast and topgallant-studding-sails.

Add the number of cloths in the head and foot, and halve the product, to make it square; then multiply by the depth of the middle cloth; and add the quantity in the linings, bands and pieces, and the quantity in the foot-gores, when the foot is cut hollow.

To find the quantity in the foot-gores.

Add together the number of inches gored in each cloth on one side of the sail, and multiply the product by half the number of gored cloths, and divide by 36, to bring that into yards.

Rule 2.—To find the quantity of canvas in a mizen-course.

Add the depth of the fore and after-leeche together, and halve the product for a medium depth; then multiply the medium depth by the number of cloths; and add to that the additional canvas contained in the linings, bands, pieces, and foot-gores.

To find the quantity in the foot-gores.

The number of cloths in the sail must be multiplied by the additional length, that the square cloth in the middle is more than those at the tack and clue; then, the gores to the tack and clue being subtracted, the remainder is the quantity in inches, which divided by 36 gives the number of yards.

Rule 3.—To find the quantity of canvas contained in sprit-sail-courses; lower studding-sails; sloop's square sails, or cross-jack; and sloop's water-sails.

Multiply the number of cloths by the shortest depth, add the quantity in the bands and pieces, and the quantity in the foot-gores, when the foot is cut hollow; by Rule 1.

Rule 4.—To find the quantity of canvas contained in driver-boom-sails; brig's main-sails; cutter's main-sails; cutter's try-sails; likewise sloop's and smack's.

Add together the number of cloths in the head and foot, and halve the product to make it square; add together the depth of the fore and after-leeches, and halve that sum for a medium depth; then multiply the number of square cloths by the medium depth, and add the quantity in the pieces and foot-gores.

To find the quantity in the foot-gores.

Add together the gores from the tack to the first square cloth in the foot, and multiply half the sum by the number of cloths in the foot; then (if there are gores to the clue) add together the gores from the clue to the first square cloth in the foot, and multiply half the sum by the number of cloths gored to the clue; which subtracted from the product of the gores to the tack, gives the answer.

Rule 5.—To find the quantity of canvas contained in jibs; main and fore-stay-sails; fore-topmast stay-sails; sloop's, smack's, and boat's fore-sails and latteen-sails.

Multiply half the number of cloths by the depth of the leeche, and add the quantity in the bands, pieces, and foot-gores, if any.

To find the quantity in the foot-gores.

Multiply half the number of cloths in the foot by the regular gore per cloth, and that product multiplied by the whole number of cloths in the foot gives the answer in inches, which divide by 36, to bring into yards.

Rule 6.—To find the quantity of canvas contained in mizen-stay-sails; main-topmast-stay-sails; mizen-topmast-stay-sails; middle stay-sails; main-topgallant-stay-sails; gaff-top-sails; ringtail-sails; settee-sails; and boat's sprit-sails.

Add the depth of the tack, bunt, or fore-leeche, to the depth of the after-leeche, and halve them for a medium depth: add the number of cloths in the head and foot together, (when not equal,) and halve them, to reduce them square; then multiply the number of squared cloths by the medium depth, and add to that the additional canvas contained in the linings, bands, and pieces.

Description of each Sail.

MAIN-COURSE, 1. Plate IV. Rigging, fig. 2.

This sail is quadrilateral, square on the head. It bends at the head to the main-yard, and extends within eighteen inches of the cleats on the yard-arms, and drops to clear the foot from the boat on the booms.

Guns - - -	Sort of Canvas.	110	98	80	74	50	44	38	36	24	18	16	Main-sail.	
													Brig.	Cutter.
Tons - - -		2165	1970	1900	1860	1200	1120	1040	920	600	425	360	200	180
Number of cloths { head in the - - } foot	N ^o	48	46	48	47	40	40	39	38	31	28	27	12½	24
	1	50	48	50	49	42	42	41	40	33	30	29	19½	34
Depth in yards - -		14½	14	16½	16	13	13½	13¼	13¼	11	10	9½	{ 13 8¼	24
														18
Yards in the sail -		710½	658	808½	768	533	553½	540	516¾	352	290	266	174	609
— reef-bands -	1	19	18¾	22	20	17	17	16½	16	13	12	11½	21	27
— middle band -	5 to 6	30	28½	31	30	26	26	25¼	25	20	18½	17½	Peek-Piece.	
— leech-linings -	1	33½	31¾	37	35¾	28½	29½	29	29	24½	22¾	22	8¾	18
— buntline-cloths	1	19	18½	23	21½	17½	17¾	17	17	14	13½	13	5	8
— gores - - -	1	18¾	14¾	19¼	14½	8	9½	8¾	8¾	8	9	9	3½	45
Totals -		830¾	769¾	940¾	889¾	630	653¼	636½	612½	431½	365¾	339	213¼	709
Bolt-rope on { head the - - } foot - - - leeches	Inches.												Malt-Leech.	
		2½	2½	2½	2½	2	2	1¾	1¾	1½	1½	1½	3	3
		6	5¾	6	5¾	5	4¾	4½	4½	4	3½	3½	1½	1½

Gores.—One cloth is gored on each *leech*; and the gore on the *foot* is of one inch *per* cloth, beginning at two cloths within the nearest buntline-*cringle*, and increasing to the clues. Sometimes, in merchant-ships, two cloths are gored on the leeches, and the gore on the foot is two inches *per* cloth.

For *tablings*, *reef-bands*, *middle bands*, and *buntline-cloths*, consult the first process in sail-making; and sewing them on, the second process; likewise the *seams*, *reef*, and *head-holes*.

In sewing on the bolt-rope, two inches of *slack-cloth* should be taken up in every cloth in the head and foot, and one inch and a half in every yard in the leeches.

Clues are made with clue-rope two inches larger than the foot-rope, for ships of 50 guns and upwards; and one inch and a half larger for ships under 50 guns; and those in merchant-ships are in proportion.

Marline-holes extend from the clue to the lower bowline-*cringle* on the leech; and to the first buntline-*cringle* at the foot.

Reef-*cringles*: one is made on the leeches at the end of each reef-band; three bowline-*cringles* are made at equal distances between the lower reef-*cringle* and the clue; and *buntline-*cringles** are made on the *foot-rope*, one at the end of each buntline-cloth.

To find the quantity of canvas, refer to Rule 1.

FORE-COURSE, 5. *Plate IV. fig. 2.*

This fail is quadrilateral, square on the head. It bends at the head to the fore-yard, and extends within eighteen inches of the cleats on the yard-arms, and drops to clear the foot of the main-stay.

Guns - - - -	Sort of Canvas.	110	98	80	74	50	44	38	36	24	18	16	Brig.
Tons - - - -		2165	1970	1900	1860	1200	1120	1040	920	600	425	360	200
Number of cloths { head -	N ^o	42	40	41	40	35	35	34	33	27	25	24	19
in the - - { foot -	1 to 2	40	38	39	38	33	34	33	32	24	24	23	18
Depth in yards - -		12 $\frac{1}{4}$	11 $\frac{1}{2}$	13 $\frac{1}{2}$	13	11 $\frac{1}{2}$	11 $\frac{1}{2}$	11	11	9	9	8 $\frac{3}{4}$	7 $\frac{1}{2}$
Yards in the fail - -		502 $\frac{1}{4}$	448 $\frac{1}{2}$	540	507	391	396 $\frac{3}{4}$	368 $\frac{1}{2}$	357 $\frac{1}{2}$	238 $\frac{1}{2}$	220 $\frac{1}{2}$	205	138 $\frac{3}{4}$
reef-bands - -	1 to 2	17 $\frac{1}{2}$	16	17 $\frac{1}{2}$	17	13 $\frac{3}{4}$	13 $\frac{3}{4}$	14 $\frac{1}{2}$	13 $\frac{1}{2}$	10 $\frac{1}{2}$	10 $\frac{1}{2}$	10	7
middle band - -	5 to 6, 7	24 $\frac{1}{2}$	23	24 $\frac{1}{2}$	24 $\frac{1}{2}$	21 $\frac{1}{2}$	21 $\frac{1}{2}$	20	19 $\frac{1}{2}$	15 $\frac{1}{2}$	15 $\frac{1}{2}$	14 $\frac{1}{2}$	11 $\frac{1}{2}$
leech-linings - -	1 to 2	27 $\frac{1}{4}$	26	30	29 $\frac{1}{2}$	24	24 $\frac{1}{2}$	24	24	20	20	19 $\frac{1}{2}$	16 $\frac{1}{2}$
buntline-cloths - -	1 to 2	16	15 $\frac{3}{4}$	18 $\frac{1}{2}$	17 $\frac{1}{2}$	14 $\frac{1}{4}$	14 $\frac{3}{4}$	14	14	12	12	11 $\frac{1}{4}$	7 $\frac{1}{2}$
gores - -	1 to 2	11	10 $\frac{3}{4}$	10 $\frac{1}{2}$	10	6	6	5 $\frac{3}{4}$	5 $\frac{3}{4}$	5 $\frac{1}{2}$	5 $\frac{1}{2}$	5 $\frac{1}{4}$	3 $\frac{1}{4}$
Totals -		599	540	640 $\frac{1}{2}$	605 $\frac{1}{2}$	470 $\frac{1}{2}$	477 $\frac{1}{4}$	446 $\frac{3}{4}$	434 $\frac{1}{4}$	303 $\frac{1}{2}$	284 $\frac{1}{4}$	266 $\frac{1}{2}$	184 $\frac{1}{2}$
Bolt-rope on the { head -	Inches.	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2	2	1 $\frac{3}{4}$	1 $\frac{3}{4}$	1 $\frac{3}{4}$	1 $\frac{3}{4}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$
{ foot -		5 $\frac{1}{2}$	5 $\frac{1}{4}$	5	5	4 $\frac{1}{4}$	4 $\frac{1}{4}$	4	4	3 $\frac{1}{2}$	3	2 $\frac{1}{2}$	2 $\frac{1}{2}$
{ leeches -		5 $\frac{1}{2}$	5 $\frac{1}{4}$	5	5	4 $\frac{1}{4}$	4 $\frac{1}{4}$	4	4	3 $\frac{1}{2}$	3	2 $\frac{1}{2}$	2 $\frac{1}{2}$

Gores.—One cloth is gored on each *leech*, and a gore is made on the *foot*, to drop the clue five to six inches *per* cloth, beginning at two cloths within the nearest buntline-crinkle, and increasing to the clues. Sometimes two cloths are gored on each leech in merchant-ships.

This fail only differs from the former in the *buntline-crinkles* having only two; the upper buntline-crinkle is made

in the middle of the leech, and the lower one equally distant from the upper one and the clue.

Marline-holes are made in the tabling, from the clue to the nearest buntline-crinkle on the foot, and one-eighth of the depth of the fail up the leech. They are turned on the contrary side to the roping, in fixing the fail.

To find the quantity of canvas, refer to Rule 1.

MIZEN-COURSE, 9. *Plate IV. fig. 2.*

This fail is quadrilateral, and made of canvas N^o 2, from 36 guns and upwards; N^o 3, to 24 guns; and to 16 guns N^o 4. The head is bent to the gaff, and extends within nine inches of the cleats. The fore-leech is attached to the mizen-mast within six or seven feet of the deck.

Guns - - - -	110	98	80	74	50	44	38	36	24	18	16
Tons - - - -	2165	1970	1900	1860	1200	1120	1040	920	600	425	360
Number of cloths { head -	17	16	16	16	13	13	13	13	10	9	9
in the - - { foot -	18	17	17	17	14	14	14	14	11	10	10
Depth of the leech { fore -	10 $\frac{1}{2}$	9 $\frac{1}{2}$	11	11	8 $\frac{1}{2}$	11 $\frac{1}{2}$	11 $\frac{1}{2}$	10 $\frac{1}{2}$	9	8	7 $\frac{3}{4}$
in yards - - { aft -	20 $\frac{1}{2}$	19 $\frac{1}{2}$	21	21	16 $\frac{1}{4}$	18 $\frac{1}{2}$	18 $\frac{1}{4}$	18 $\frac{1}{4}$	15 $\frac{1}{2}$	14 $\frac{1}{2}$	13 $\frac{1}{2}$
Yards in the fail - -	271 $\frac{1}{4}$	239 $\frac{1}{4}$	264	264	167	202 $\frac{1}{2}$	199 $\frac{1}{4}$	195 $\frac{3}{4}$	122 $\frac{1}{2}$	103 $\frac{1}{2}$	100 $\frac{3}{4}$
reef-band - -	3 $\frac{1}{2}$	3 $\frac{1}{2}$	3 $\frac{1}{2}$	3 $\frac{1}{2}$	2 $\frac{3}{4}$	3	3	3	2	2	2
nock and peek-pieces - -	2	2	2	2	2	2	2	2	2	2	2
clue-pieces - -	5	5	5	5	5	5	5	5	5	5	5
gores - -	10	9	9 $\frac{1}{2}$	9 $\frac{1}{2}$	6	7 $\frac{1}{2}$	7	7	5	4 $\frac{1}{2}$	4
Totals -	292	258 $\frac{3}{4}$	284	284	182 $\frac{3}{4}$	220	216 $\frac{1}{4}$	212 $\frac{3}{4}$	136 $\frac{1}{2}$	117 $\frac{1}{2}$	113 $\frac{3}{4}$
Bolt-rope on the { head -	Inches.	1 $\frac{3}{4}$	1 $\frac{3}{4}$	1 $\frac{3}{4}$	1 $\frac{3}{4}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$
{ foot -		3 $\frac{1}{2}$	3	3	3	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2	2	2
{ fore-leech -		4 $\frac{1}{2}$	4	4	4	3	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$
{ after-leech -		3 $\frac{1}{4}$	3	3	3	2 $\frac{1}{2}$	2 $\frac{1}{4}$	2 $\frac{1}{4}$	2	1 $\frac{3}{4}$	1 $\frac{1}{4}$

Gores.—The head is cut with a gore of 16 to 22 inches *per* cloth, agreeable to the peek: the foot is gored one inch *per* cloth, leaving two cloths square in the middle. One cloth is gored on the mast-leech in the navy, and sometimes two cloths in merchant-ships.

For *seams, tablings, and head-holes*, consult the three processes in sail-making.

This sail has a *reef-band* six or eight inches broad, at one-fifth of the depth of the mast-leech from the foot.

Reef-bands are pieces of log-line sewed on to the reef-band, at each seam on both sides of the sail. One end of each hank is spread open, and each strand securely sewed; the other end of each hank is whipped: or they may be fixed on thus: the line is thrust through the sail, and securely

sewed to it on one side, by opening the strands a little, so as to lay them flat on the canvas.

Lining.—The after-leech is lined from the clue with one breadth of canvas up the leech, and the *nock* and *peek* with pieces so cut from each other, that each contains one yard.

Marline-holes extend two feet each way from the clue.

Bolt-rope-clue, and sewing it on, consult the third process in sail-making.

One *cringle* is made on each leech at the ends of the reef-band; and one at the distance of every three-quarters of a yard on the mast-leech; or sometimes holes are worked in the tabling of the mast-leech; a cringle is also made five yards from the clue on the after-leech for the throat-brails.

To find the quantity of canvas, refer to Rule 2.

SPRITSAIL-COURSE, 13. Plate IV. fig. 2.

This sail is quadrilateral, square on the head, foot, and leeches, and made of canvas N^o 2, from 50 guns and upwards; and N^o 3, to 18 guns; and all under of N^o 4. It is bent at the head to the sprit-sail-yard, extending within nine inches of the cleats on the yard-arms.

Guns	-	-	-	-	110	98	80	74	50	44	38	36	24	18	16
Tons	-	-	-	-	2165	1970	1900	1860	1200	1120	1040	920	600	425	360
Number of cloths	{	head	-	30	28	29	29	25	25	25	25	24	19	17	17
		foot	-	30	28	29	29	25	25	25	25	24	19	17	17
Depth in yards	-	-	-	9	9	8½	8½	7	6½	6	6	5½	5½	5	5
Yards in the sail	-	-	-	270	252	246½	246½	175	162½	150	144	104½	85	85	85
		reef-bands	-	9½	8¾	9	9	8	8	8	7	6	5	5	5
Totals	-	-	-	279½	260½	255½	255½	183	170½	158	151	110½	90	90	90
Bolt-rope on the	{	Inches.	-												
		head	-	1¾	1¾	1½	1½	1½	1½	1½	1½	1½	1½	1¼	1¼
		foot	-	3¾	3¾	3	3	2½	2¾	2¾	2¾	2	2	1¾	1¾
		leeches	-	3¾	3¾	3	3	2½	2¾	2¾	2¾	2	2	1¾	1¾

For *seams, tablings, reef and head-holes*, consult the two first processes of sail-making.

Two *reef-bands*, one-third of the breadth of a cloth, are sewed on diagonally; the ends on the leeches being 27 inches from the clues, and those at the head on the second or third seam from the earrings. Sometimes a reef-band is sewed on from leech to leech, at one-fifth of the depth of the sail from the head.

A *water-hole*, from four to six inches diameter, is made

in the second cloth from each leech, near the foot, or opposite the reef-cringles.

Marline-holes extend two feet each way from the clues.

Bolt-rope and clues, and sewing them on, consult the third process in sail-making.

A reef-crinkle is made on the leeches at the end of each reef-band, and two buntline-cringles are made on the foot-rope, at one-third of the breadth of the foot from each clue.

To find the quantity of canvas, refer to Rule 3.

MAIN-TOPSAIL, 2. *Plate IV. fig. 2.*

This sail is quadrilateral, square on the head and foot in the navy, and made of canvas N° 2, from 50 guns and upwards; and N° 3, all under. It is bent at the head to the main-topfail-yard, and extends within eighteen inches of the cleats on the yard-arms, and drops to the main-yard when the respective yards are hoisted to the hounds.

Guns - - - -	110	98	80	74	50	44	38	36	24	18	16	Brig.	Cutt.
Tons - - - -	2165	1970	1900	1860	1200	1120	1040	920	600	425	360	200	180
Number of cloths { head -	31	30	31	31	26	26	25	24	20	18	17	13	23
{ foot -	49	48	48	48	40	40	40	38	32	29	28	19 $\frac{1}{2}$	27
Depth in yards - -	21	20	20 $\frac{1}{4}$	20 $\frac{1}{4}$	16 $\frac{1}{4}$	16 $\frac{3}{4}$	16 $\frac{1}{2}$	16 $\frac{1}{4}$	13 $\frac{3}{4}$	13	12	9 $\frac{3}{4}$	13 $\frac{3}{4}$
Yards in the fail - -	840	780	799 $\frac{1}{2}$	799 $\frac{1}{2}$	536 $\frac{1}{4}$	544 $\frac{1}{4}$	536 $\frac{1}{4}$	503 $\frac{3}{4}$	357 $\frac{1}{2}$	305 $\frac{1}{2}$	270	158 $\frac{1}{4}$	362
— reef-bands - -	56	53	54	54	34	34	33	32	27 $\frac{1}{2}$	27	25	9 $\frac{1}{4}$	10
— middle band - -	27	25	26	26	21 $\frac{1}{2}$	22	22	21 $\frac{3}{4}$	17 $\frac{1}{2}$	14 $\frac{1}{2}$	14	2 $\frac{1}{4}$	Gores.
— leech-linings - -	44	42 $\frac{1}{2}$	42 $\frac{5}{8}$	42 $\frac{5}{8}$	34 $\frac{3}{4}$	35	34	34	26	25	25	20 $\frac{1}{2}$	6
— top-lining - -	75	74	70	70	55 $\frac{1}{2}$	54	53	53	37 $\frac{1}{2}$	28	26 $\frac{1}{2}$	15	14
— buntline-cloths -	12	12	12	12	10	10 $\frac{1}{4}$	9 $\frac{3}{4}$	9 $\frac{3}{4}$	8 $\frac{1}{4}$	6 $\frac{3}{4}$	6 $\frac{1}{2}$	11	
Totals -	1054	986 $\frac{1}{2}$	1004 $\frac{1}{2}$	1004 $\frac{1}{2}$	692	700	688	654 $\frac{1}{4}$	474 $\frac{1}{4}$	406 $\frac{3}{4}$	367	217	392
	Inches.												
Bolt-rope on the { head -	2 $\frac{1}{2}$	2 $\frac{1}{4}$	2 $\frac{1}{4}$	2 $\frac{1}{4}$	2	2	2	1 $\frac{3}{4}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$
{ foot -	5 $\frac{3}{4}$	5 $\frac{1}{2}$	5 $\frac{1}{2}$	5 $\frac{1}{2}$	5	5	5	4 $\frac{1}{4}$	3 $\frac{3}{4}$	3	3	2 $\frac{1}{4}$	2 $\frac{1}{4}$
{ leeches -	5	4 $\frac{3}{4}$	4 $\frac{3}{4}$	4 $\frac{3}{4}$	4 $\frac{1}{4}$	4 $\frac{1}{4}$	4 $\frac{1}{4}$	3 $\frac{1}{2}$	3	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{4}$	2 $\frac{1}{4}$

Gores.—The cloths on the leeches are gored sufficiently for the foot to spread the cleats on the arms of the main-yard. In merchant-ships the *foot* is gored from two to four inches per cloth, one-third of the breadth of the foot from the clues.

For *seams, tablings, reef* and *head-holes*, refer to the first process in fail-making.

Reef-bands.—This fail has mostly four reef-bands of N° 2 cloth, from 50 guns upwards; N° 3 to 18; and N° 4 for 16 guns; put on at one-eighth of the fail afunder, the upper one being kept at that distance from the head. In merchant-ships the reef-bands are mostly put on farther distant from each other.

Middle band is of N° 5 cloth, from 74 guns upwards; N° 6 to 18; and N° 7 for 16 guns; put on half-way between the lower reef-band and the foot.

Leech-lining is of N° 2 cloth, from 50 guns upwards; N° 3 to 18; and N° 4 for 16 guns. (See first process of fail-making.) Merchant-ships have leech-linings nine inches broad at the head, and fifteen inches broad at the foot.

Top-lining of N° 6 cloth, from 18 guns upwards, and N° 7 for 16 guns; covers one-fifth of the cloths on the aft-side of the *foot* in the middle of the fail. In merchant-ships the top-lining covers one-third of the cloths in the foot.

Two *maft-cloths* are put on in the middle of the fail, on the aft-side, between the middle band and lower reef-band.

Two *buntline-cloths* (the same N° of cloth as the leech-lining) are put on the fore-side of the fail, and one each side of the top-lining; their ends are carried up under the middle band, which is tabled on them. In merchant-ships the buntline-cloths are half a yard shorter than the top-linings.

Bolt-rope.—Three inches of *flack-cloth* are taken up in sewing on the bolt-rope in every cloth on the head and foot; two inches are allowed for every cloth left open in the top-brim; and one inch and a half is taken up in every yard in the leeches. The bolt-rope along the top-brim, and for one cloth and a half on each side beyond, is wormed, parcelled, and lerved as the clues, and is marled to the fail; but sometimes the whole length of the foot-rope, from clue to clue, is wormed, parcelled, &c. See third process in fail-making.

Clues.—The clues are made of the foot-rope, which is left sufficiently long for that purpose, and splice into the leech-rope at the lower bowline-crinkle. It is wormed, parcelled, and lerved at the clues, and three feet each way from them: it is marled on to the fail the extent of the serving on each side of the clues, which are seized as those of the main-course.

The *marline-holes* extend three feet each way from the clues, and along the breadth of the top-lining at the top-brim.

Crinkles.—One *reef-crinkle* is made on the leeches at the end of each reef-band, and a *reef-tackle-pendant-crinkle* between the lower reef and upper bowline-crinkle; below these are four *bowline-crinkles*; the upper one is in the middle of the leech, and the other three are equally distant from each other between the upper one and the clue. One *buntline-crinkle* is made in the middle of each buntline-cloth at the foot. In merchant-ships three bowline-crinkles only are made on the leeches.

To find the quantity of canvas contained in this fail, refer to Rule 1.

FORE-TOPSAIL, 6. *Plate IV. fig. 2.*

This sail is quadrilateral, square on the head and foot in the royal navy, and made of canvas, the same as the main-topfail. The head is bent to the fore-topfail-yard, extending at the head within 18 inches of the cleats on the yard-arms.

Guns - - - -	110	98	80	74	50	44	38	36	24	18	16	Brig.
Tons - - - -	2165	1970	1900	1860	1200	1120	1040	920	600	425	360	200
Number of cloths { head -	27	26	28	28	22	22	22	22	17	16	15	13
in the - - { foot -	43	41	42	42	35	34	34	33	28	25	24	19½
Depth in yards - -	19	18	18½	18	14¾	14¾	14½	14¼	12¼	11¾	10½	9½
Yards in the fail - -	665	603	647½	630	420½	413	406	391½	276½	240½	204½	154½
reef-band - -	45	41	46	46	30	30	30	29½	23	22	21	9
middle band - -	23	22	23	23	19	19	19	19	15	13½	12½	2½
leech-linings - -	40	38	39	38	31½	31½	30½	30	25½	24½	21½	20
top-linings - -	58	56	57	56	40¾	40	39	39	30½	27	23½	16
buntline-cloths - -	10½	10½	10	9½	9	9	8½	8½	7½	6½	6	9½
Totals -	841½	770½	822½	802½	550½	542½	533	517½	378½	334½	288½	212½
Bolt-rope on the { head -	2	2	2	2	1½	1½	1½	1½	1½	1½	1½	1½
{ foot -	5¼	5	5	5	4	4	4	3¾	3¾	2¾	2¾	2¾
{ leeches -	4½	4¼	4¼	4¼	3¾	3¾	3¾	3	3	2¾	2¾	2¾

Gores, and every other particular, the same as the main-topfail.

MIZEN-TOPSAIL, 10. *Plate IV. fig. 2.*

This sail is quadrilateral, cut square on the head, and made of canvas N^o 4, from 50-gun ships and upwards, N^o 5 to 18 guns; and of N^o 6, those of 16 guns. It is bent at the head to the mizen-topfail-yard, and drops to the cross-jack-yard, extending within twelve inches of the cleats on the yard-arms.

Guns	110	98	80	74	50	44	38	36	24	18	16
Tons	2165	1970	1900	1860	1200	1120	1040	920	600	425	360
Number of cloths { head	21	20½		21	17	18	18	17	13½	12	12
in the - - { foot	31	29	30	30	25½	25½	25½	25	20	18	17½
Depth in yards - -	14½	13¾	14¼	14			11¾	11¼	9¼		7¾
Yards in the fail - -	377	340	363¼	357	233¾	255½	255	236¼	155		113¾
reef-bands	21	20½	21	21	20¼	20½	20½	18¾	9½		8½
middle band	16¾	16	16	16	15¾	16	16	15	11		9½
leech-linings	31½	30½	31¼	31	27½	28	28	26	21		18½
top-lining	38½	37¼	38	38	33	34	34	32	18½		14
buntline-cloths	8¼	8¼	8¼		6¾	7	7	7	6		4½
gores	4	4	4		4	4	4	4	4		4
Totals	497	457	481¾	475	341	365	365	339	225	175¼	172¾
Bolt-rope on the { head	1½				1½	1½	1½	1½	1½	1½	1½
{ foot	3½			3½	3	3	3	3	2¾	2¾	2¾
{ leeches				2¾	2½	2½	2½	2½	2¼	1¾	1¾

Gores.—The cloths on the leeches are gored sufficiently for the foot to spread to the cleats on the arms of the cross-jack-yard. The gore on the foot is three-quarters of a yard deep, and begins at two cloths from the buntline-crinkle, on the side next the clues. In merchant-ships the foot is sometimes square.

For *seams*, &c. see MAIN-TOPSAIL.

Reef-bands.—For 36-gun ships and upwards, to have three reef-bands of N^o 4 canvas, at one-eighth of the

depth of the fail afunder from the head; and 24-gun ships and under of the same canvas the fail is made of, and two reefs only one-seventh of the depth of the fail afunder. Merchant-ships have seldom more than two reef-bands.

Middle band, of N^o 6 canvas, for 36-gun ships and upwards; and N^o 7 all under, put on as main-topfail. Merchant-ships have none.

Leech-linings, &c. &c. similar to the main-topfail.

MAIN-TOPGALLANT-SAIL, 3. *Plate IV. fig. 2.*

This fail is quadrilateral, and square on the head and foot, in the royal navy, and made of canvas N^o 6, from 50-gun ships upwards; and all ships under, of N^o 7. The head is bent to the main-topgallant-yard, and extends within six inches of the cleats on the yard-arms.

Guns	-	-	-	-	110	98	80	74	50	44	38	36	24	18	16	Brig.	Cutter.
Tons	-	-	-	-	2165	1970	1900	1860	1200	1120	1140	920	600	425	360	200	180
Number of cloths	{	head	-	-	23	21	22	22	18	18	18	16	14	13	12	10½	7
in the		foot	-	-	31	30	31	31	27	26	26	25	21	19	18	14	17
Depth in yards	-	-	-	-	10½	10	10	10	8	8¼	8¼	7¾	6¾	6½	6	5½	6½
Yards in the fail	-	-	-	-	283½	255	265	265	180	181½	181½	159	117¾	104	90	70½	78
Yards in the clue and	{	-	-	-	3	3	3	3	3	3	3	3	3	3	3	2½	3
caring-pieces		-	-	-													
Totals	-	-	-	-	286½	258	268	268	183	184½	184½	162	120¾	107	93	73	81
					Inches.												
Bolt-rope on the	{	head	-	-	1½	1½	1½	1½	1½	1½	1½	1½	1½	1	1	1	1
		foot	-	-	2¼	2¼	2¼	2¼	2¼	2¼	2¼	2¼	2	1¾	1½	1½	1½
		leeches	-	-	2¾	2¾	2¾	2¾	2¾	2¾	2¾	2¾	2	1¾	1½	1½	1½

Gores.—The cloths on the leeches are gored sufficiently for the foot to spread to the cleats on the arms of the maintop-fail-yard. A gore of two or three inches *per cloth* is often made on the foot, in merchant-ships, beginning at one-third of the breadth of the foot from the clue.

For *seams, tablings, head-holes, sewing on the bolt-rope, and clues*, refer to the three processes of sail-making.

The cloth at the clue is so cut as to fall to the foot, and form its own *lining*; and earing-pieces, of a quarter of a yard, are put on each corner, at the head.

Three *bowline-cringles* are made on each leech, the upper one in the middle, and the others equally afunder between that and the clue.

To find the quantity of canvas, refer to Rule 1.

FORE-TOPGALLANT-SAIL, 7. *Plate IV. fig. 2.*

This fail bends at the head to the fore-topgallant-yard, and is so much like the former as only to need the following dimensions.

[illegible]

MIZEN-TOPGALLANT-SAIL, 11. *Plate IV. fig. 2.*

This sail is quadrilateral, square on the head and foot, in the navy; made of canvas N^o 7, from 50-gun ships upwards, and all under of N^o 8. The head bends to the mizen-topgallant-yard, extending within six inches on the cleats on the yard-arms.

Guns	-	-	-	-	110	98	80	74	50	44	38	36	24	18	16
Tons	-	-	-	-	2165	1970	1900	1860	1200	1120	1040	920	600	425	360
Number of cloths in the	{	head	-	15	15	15	15	12 $\frac{1}{2}$	13	13	12 $\frac{1}{2}$	10 $\frac{1}{2}$	8	8	
		foot	-	22	21	21	21	17 $\frac{1}{2}$	19	19	18	14	13	12	
Depth in yards	-	-	-	-	7	7	7	7	6 $\frac{1}{4}$	6 $\frac{1}{4}$	6 $\frac{1}{4}$	6 $\frac{1}{4}$	5	4 $\frac{1}{2}$	4 $\frac{1}{2}$
Yards in the fail	-	-	-	-	129 $\frac{1}{2}$	126	126	126	93 $\frac{3}{4}$	100	100	95 $\frac{1}{2}$	61 $\frac{1}{4}$	47 $\frac{1}{4}$	45
Yards in the clue and earing- pieces	{		-	1	1	1	1	1	1	1	1	1	1	1	1
			-												
Totals				-	130 $\frac{1}{2}$	127	127	127	94 $\frac{3}{4}$	101	101	96 $\frac{1}{4}$	62 $\frac{1}{4}$	48 $\frac{1}{4}$	46
					Inches.										
Bolt-rope on the	{	head	-	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1	1	1	1	1	1	1	1
		foot	-	2	2	2	2	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$
		leeches	-	2	2	2	2	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	

Gores.—The leeches are gored sufficiently for the foot to spread to the cleats on the arms of the mizen-topgallant-yard. In merchant-ships a small gore is sometimes made on the foot, beginning at one-third of the breadth from the clue.

Pieces, at the clues and earings, are each a quarter of a yard in length.

For the *seams*, *tablings*, *head-holes*, *clues*, and *bolt-rope*, consult the three processes of sail-making.

To find the quantity of canvas, refer to Rule 1.

MAIN-ROYAL, 4. *Plate IV. fig. 2.*

This sail is quadrilateral, square on the head and foot, made of canvas N^o 8. The head is bent to the main-royal-yard, and extends within four inches of the cleats on the yard-arms.

Guns	-	-	-	-	110	98	80	74	50	44	38	36	24	18	16	Brig.
Tons	-	-	-	-	2165	1970	1900	1860	1200	1120	1040	920	600	425	360	200
Number of cloths	{	head	-	16	15	14	14	14	11 $\frac{1}{2}$	11	11	11	9 $\frac{1}{2}$	9	8	7 $\frac{1}{2}$
		foot	-	23	22	21	21	21	18	17	17	16	13 $\frac{1}{2}$	13	12 $\frac{1}{2}$	11
Depth in yards	-	-	-	8	7 $\frac{1}{2}$	7	7	7	6	6 $\frac{1}{4}$	6 $\frac{1}{4}$	6 $\frac{1}{4}$	4 $\frac{1}{4}$	4	3 $\frac{1}{2}$	4
Yards in the fail	-	-	-	156	138 $\frac{3}{4}$	121 $\frac{1}{2}$	121 $\frac{1}{2}$	88 $\frac{1}{2}$	87 $\frac{1}{2}$	87 $\frac{1}{2}$	84 $\frac{3}{4}$	54 $\frac{1}{4}$	44	38 $\frac{1}{2}$	37	
				Inches.												
Bolt-rope on the	{	head	-	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1	1	1	1	1	1	1	1	1
		foot	-	2	2	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$
		leeches	-	2	2	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$

Gores.—The cloths on the leeches are gored sufficiently for the foot to spread to the cleats on the main-topgallant-yard-arms.

For *seams*, *tablings*, *head-holes*, and *clues*, consult the three processes in sail-making.

To find the quantity of canvas, refer to Rule 1.

FORE-ROYAL, 8. *Plate IV. fig. 2.*

This sail is bent at the head to the fore-royal-yard, and is so much like the former, as only to need the following dimensions.

Guns - - - -	110	98	80	74	50	44	38	36	24	18	16	Brig.
Tons - - - -	2165	1970	1900	1860	1200	1120	1040	920	600	425	360	200
Number of cloths { head -	13	12	12	12	10	10	10	10	8½	8	7½	7½
in the - { foot -	20	19	19	19	15	15	15	15	12½	11½	11	11
Depth in yards - -	7	6¾	6¾	6¾	5	5	5	5	4½	3¾	3½	4
Yards in the fail - -	115½	104½	104½	104½	62½	62½	62½	62½	47½	36½	32½	37
Bolt-rope the same size as the main-royal.												

MIZEN-ROYAL, 12. *Plate IV. fig. 2.*

This sail is bent at the head to the mizen-royal-yard, and so like the main-royal, as only to need the following dimensions.

Guns - - - -	110	98	80	74	50	44	38	36	24	18	16	
Tons - - - -	2165	1970	1900	1860	1200	1120	1040	920	600	425	360	
Number of cloths { head -	11	11	11	11	9	9	9	9	7	4	4	
in the - { foot -	15	15	15	15	13	13	13	13	11	8	8	
Depth in yards - -	5½	5½	5½	5½	4¾	4¾	4¾	4¾	3¾	3¾	3	
Yards in the fail - -	71½	71½	71½	71½	52½	52½	52½	52½	29½	19½	18	
	Inches.											
Bolt-rope on the { head -	1	1	1	1	1	1	1	1	¾	¾	¾	
foot -	1¾	1¾	1¾	1¾	1½	1½	1½	1½	1	1	1	
leeches -	1¾	1¾	1¾	1¾	1½	1½	1½	1½	1	1	1	

MAIN-STAYSAIL, 1. *Plate IV. fig. 1.*

This sail is triangular, square on the foot in the royal navy, and made of canvas N^o 1, from 50-gun ships upwards, N^o 2 to 18 guns, and all under of N^o 3. It is extended upon the main-stay-fail-stay, and drops to clear the foot of the boats upon the beams. This sail is seldom used in large vessels.

Guns	-	-	-	-	110	98	80	74	50	44	38	36	24	18	16	Brig.
Tons	-	-	-	-	2165	1970	1900	1860	1200	1120	1040	920	600	425	360	200
Number of cloths in the foot					32	31	32	32	26	25	24	24	22	18	17	{ head 13 foot 14
Depth in yards	-	-			15	14	16	16	13	13½	13¼	13	11½	9½	9½	
Yards in the fail	-	-			240	217	256	256	169	168¾	159	156	126½	85½	80¾	67½
Yards in the tack and peek-pieces	-	-			2	2	2	2	2	2	2	2	2	2	2	1
Yards in the clue-piece	-				2	2	2	2	2	2	2	2	2	2	2	1½
Totals	-				244	221	260	260	173	172¾	163	160	130½	89½	84¾	70
					Inches.											
Bolt-rope on the	{	head	-	-	3¼	3¼	3	3	2¾	2¾	2½	2½	2½	2	2	2
		foot	-	-	3¼	3¼	3	3	2¾	2¾	2½	2½	2½	2	2	2
		after-leech	-	-	3¼	3¼	3	3	2¾	2¾	2½	2½	2½	2	2	2

Gores.—A regular gore is made on the head, of from 17 to 19 inches *per* cloth; the depth of the gore on each cloth in the head, is found by dividing the depth of the leech by the number of cloths. The cloth at the tack is so cut as to fall to the foot, and form its own *lining*. The *clue-piece* extends two yards up the leech, and the *peek-piece* is one yard in length.

For *seams, tablings, holes, sewing on the bolt-rope*, and *clue*, consult the three processes in sail-making.

Iron thimbles are sometimes stuck at the tack and peek; but when none, the tack and peek are the same as the clue.

A *cringle* is made on the leech for the brails, but is usually done by the seamen on board.

In merchant-ships this sail is frequently cut with a bunt, and a gore is sometimes made on the foot, with a sweep. It also frequently has a reef-band at about four feet from the foot, and sometimes a bonnet.

To find the quantity of canvas, refer to Rule 5.

FORE-STAYSAIL, 5. Plate IV. fig. 1.

This sail is triangular, square on the foot, and made of canvas N° 1, from 50-gun ships upwards, N° 2 to 18 guns, and all under of N° 3. It is extended on the fore-flay or fore-preventer-flay.

Guns - - - -	110	98	80	74	50	44	38	36	24	18	16	Brig.
Tons - - - -	2165	1970	1900	1860	1200	1120	1040	920	600	425	360	200
Number of cloths in the foot	23	22	22	22	18	17	17	17	15	14	13	9
Depth in yards - -	13	12	13 $\frac{1}{4}$	13 $\frac{1}{4}$	11	11 $\frac{1}{4}$	11	11	9 $\frac{1}{2}$	8 $\frac{1}{2}$	8	9
Yards in the fail - -	149 $\frac{1}{2}$	132	145 $\frac{3}{4}$	145 $\frac{3}{4}$	99	95 $\frac{3}{8}$	93 $\frac{1}{2}$	93 $\frac{1}{2}$	71 $\frac{1}{4}$	59 $\frac{1}{2}$	52	40 $\frac{1}{2}$
Yards in the tack and } peek-pieces - - }	1	1	1	1	1	1	1	1	1	1	1	3
Yards in the clue-piece -	2	2	2	2	2	2	2	2	2	2	2	
Totals -	152 $\frac{1}{2}$	135	148 $\frac{3}{4}$	148 $\frac{3}{4}$	102	98 $\frac{5}{8}$	96 $\frac{1}{2}$	96 $\frac{1}{2}$	74 $\frac{1}{4}$	62 $\frac{1}{2}$	55	43 $\frac{1}{2}$
Bolt-rope as the main-flay-fail.												

Gores.—A regular gore is made on the flay or head, of from 21 to 23 inches *per* cloth. The remainder of this sail is so much like the former as to need no further description.

FORE-TOPMAST-STAYSAIL, 6. Plate IV. fig. 1.

This sail is triangular, cut square on the foot, and made of canvas N° 5, from 50-gun ships upwards, and all under of N° 6. It is hoisted on the fore-topmast-flay-fail-flay. The leech is generally the same depth as the fore-topfail. In merchant-ships, one cloth only is allowed in the foot for every yard in the depth of the leech.

Guns - - - -	110	98	80	74	50	44	38	36	24	18	16	Brig.
Tons - - - -	2165	1970	1900	1860	1200	1120	1040	920	600	425	360	200
Number of cloths in the foot	22	21	21	21	17	16	16	16	14	13	12	10
Depth in yards - -	19	18	18	18	15	15	14 $\frac{1}{2}$	14	12 $\frac{1}{2}$	11 $\frac{1}{2}$	11	10
Yards in the fail - -	209	189	189	189	127 $\frac{1}{2}$	120	116	112	87 $\frac{1}{2}$	74 $\frac{3}{4}$	66	50
Yards in the tack and } peek-pieces - - }	2	2	2	2	2	2	2	2	1	1	1	3
Yards in the clue-piece -	2	2	2	2	2	2	2	2	2	2	2	
Totals -	213	193	193	193	131 $\frac{1}{2}$	124	120	116	90 $\frac{1}{2}$	77 $\frac{3}{4}$	69	53
Inches.												
Bolt-rope { head - -	2 $\frac{3}{4}$	2 $\frac{3}{4}$	2 $\frac{3}{4}$	2 $\frac{3}{4}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2	2	2	2
on the { foot - -	2 $\frac{3}{4}$	2 $\frac{3}{4}$	2 $\frac{1}{4}$	2 $\frac{1}{4}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2	2	2	2
{ after-leech - -	2 $\frac{3}{4}$	2 $\frac{3}{4}$	2 $\frac{1}{4}$	2 $\frac{1}{4}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2	2	2	2

Gores.—The flay or head is gored 30 inches *per* cloth.

For *seams, tablings, &c. &c.* refer to the main-flayfail.

JIB, 7. Plate IV. fig. 1.

This sail is triangular, made of canvas N^o 6, from ships of 50 guns and upwards, and all under of N^o 7. It is hoisted on the jib-stay. The leech is about twice the depth of the leech of the fore-stay-sail, and one cloth more is allowed for the breadth of the foot than the leech is yards in depth.

Guns - - - -	110	98	80	74	50	44	38	36	24	18	16	Brig.	Cutter.
Tons - - - -	2165	1970	1900	1860	1200	1120	1040	920	600	425	360	200	180
Number of cloths in the foot	27	26	26	26	23	22	22	21	19	17	16	12	22
Depth in yards - -	26	25	25	25	22	21	21	20	18	16	15	13	20
Yards in the sail - -	351	325	325	325	253	231	231	210	171	136	120	78	230
Yards in the gores on the foot	28	24	24	24	17	13	13	12	11½	7	6¼	8	66
Yards in the clue, peek, } and tack-pieces - - }	3	3	3	3	3	3	3	3	3	3	3	3	6
Totals -	382	352	352	352	273	247	247	225	185½	146	129¼	89	302
Bolt-rope { head or stay on the { after-leech foot -	Inches. 3½ 1¾ 1¾	3¼ 1¾ 1¾	3¼ 1¾ 1¾	3¼ 1¾ 1¾	3 1½ 1½	2¾ 1¾ 1¾	2¾ 1¾ 1¾	2¾ 1¾ 1¾	2½ 1¾ 1¾	2¼ 1¾ 1¾	2¼ 1¾ 1¾	2¼ 1¾ 1¾	6 1½ 1½

Gores.—The head or stay is cut with a small curve, or roach. The gores should be allowed full, and the curve cut fair, after the sail is sewed together; which, it is supposed, makes it fit better, when bent. The foot has an even gore of three inches *per* cloth, decreasing from the tack to the clue, which is governed by the stive of the bowsprit.

For brigs, this sail has a curve on the foot, and sometimes in merchant-ships. The seams are generally one inch broader at the foot than at the head, when cut with a curve or roach-foot.

For *seams, tablings, &c. &c.* refer to the main-stay-sail.

FLYING JIB.

This sail is made of canvas N^o 8, and so similar to the former, as only to need the following dimensions.

Guns - - - -	110	98	80	74	50	44	38	36	24	18	16	Brig.	Cutter.
Tons - - - -	2165	1970	1900	1860	1200	1120	1040	920	600	425	360	200	180
Number of cloths in the foot	16	15	16	16	14	13	13	13	11	9	9	9	10
Depth in yards - -	20	19	20	20	17	15	15	15	14	11	11	11	10
Yards in the sail - -	160	142½	160	160	119	97½	97½	97½	77	49½	49½	49½	50
Yards in the gores on the foot	19	17½	19	19	15	15	15	15	12	9	9	9	24
Yards in the clue, peek, } and tack-pieces - - }	3	3	3	3	3	3	3	3	3	3	3	3	6
Totals -	182	163	182	182	137	115½	115½	115½	92	61½	61½	61½	80

MIZEN-STAYSAIL, 8. *Plate IV. fig. 1.*

This sail is quadrilateral, cut square on the foot, and made of canvas N^o 2, from ships of 50 guns and upwards; N^o 3, to 24-gun ships; and all under, N^o 4. It is extended on the mizen-stay, and has a bunt, or fore-leech, three-fifths of the depth of the after-leech in the navy, and one-third or one-fourth of the depth of the after-leech in merchant-ships. The foot drops within six or seven feet of the quarter-deck.

Guns - - - -	110	98	80	74	50	44	38	36	24	18	16
Tons - - - -	2165	1970	1900	1860	1200	1120	1040	920	600	425	360
Number of cloths { head -	23	21	21	20 $\frac{1}{2}$	18	16 $\frac{1}{2}$	16	16	14	13	13
in the { foot -	25	23	23	22 $\frac{1}{2}$	20	18 $\frac{1}{2}$	18	18	16	15	15
Depth in yards of { after-leech	14	13	13 $\frac{1}{2}$	13 $\frac{1}{2}$	11	12 $\frac{1}{2}$	12	12	9 $\frac{1}{2}$	9	9
the { fore-leech	8 $\frac{1}{2}$	8	9 $\frac{1}{2}$	9 $\frac{1}{2}$	7	7 $\frac{1}{2}$	7	7	5 $\frac{1}{2}$	5	5
Yards in the fail - - -	270	231	247 $\frac{1}{2}$	247 $\frac{1}{4}$	171	170 $\frac{1}{2}$	161 $\frac{1}{2}$	161 $\frac{1}{2}$	112	87 $\frac{1}{2}$	87 $\frac{1}{2}$
Yards in the peek and clue- pieces - - - -	3	3	3	3	3	3	3	3	3	3	3
Yards in the bunt-lining -	4 $\frac{1}{2}$	4	4 $\frac{3}{4}$	4 $\frac{3}{4}$	3 $\frac{1}{2}$	4	3 $\frac{1}{2}$	3 $\frac{1}{2}$	2 $\frac{3}{4}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$
Totals -	277 $\frac{1}{2}$	238	255 $\frac{1}{4}$	255	177 $\frac{1}{2}$	177 $\frac{1}{2}$	168	168	117 $\frac{3}{4}$	93	93
	Inches.										
Bolt-rope on the { head -	3 $\frac{1}{4}$	3 $\frac{1}{4}$	3 $\frac{1}{4}$	3 $\frac{1}{4}$	3	3	2 $\frac{3}{4}$	2 $\frac{3}{4}$	2 $\frac{1}{2}$	2 $\frac{1}{4}$	2 $\frac{1}{4}$
{ foot -	3 $\frac{1}{4}$	3 $\frac{1}{4}$	3 $\frac{1}{4}$	3 $\frac{1}{4}$	3	3	2 $\frac{3}{4}$	2 $\frac{3}{4}$	2 $\frac{1}{2}$	2 $\frac{1}{4}$	2 $\frac{1}{4}$
{ leeches -	3 $\frac{1}{4}$	3 $\frac{1}{4}$	3 $\frac{1}{4}$	3 $\frac{1}{4}$	3	3	2 $\frac{3}{4}$	2 $\frac{1}{4}$	2 $\frac{1}{2}$	2 $\frac{1}{4}$	2 $\frac{1}{4}$

Gores.—Two cloths are generally gored on the bunt, and the head or stay is gored from 10 to 12 inches *per* cloth. If the depth of the bunt be subtracted from the depth of the leech; the remainder, divided by the number of cloths on the head, gives the depth of each gore on the stay.

For *seams* and *tablings*, consult the first process in sail-making.

Linings, &c.—The bunt is lined with half a breadth of cloth; the *clue-piece* is two yards long, and the *peek-piece* one yard. In merchant-ships the tack, peek, and nock-pieces, are generally but three-quarters of a yard in length.

Cringles.—One or two are made on the after-leech for the brails, and thimbles are stuck in the middle of the fail, to lead them through; but this is usually done by the seamen on board.

Holes on the stay, *marline-holes* at the *clue*, and *sewing on the bolt-rope*, as directed in the third process of sail-making.

Thimbles are sometimes stuck at the tack and peek; but when thimbles are not used, the tack and peek are frequently marled as the clue.

To find the quantity of canvas, refer to Rule 6.

MAIN-TOPMAST-STAYSAIL, 12. *Plate IV. fig. 1.*

This sail is quadrilateral, cut square on the foot, and made of canvas N° 5, from ships of 50 guns and upwards; and of N° 6, all under. It hoists on the main-topmast-preventer-stay. The leech is four or five yards deeper than the main-topfail, and there are one or two cloths more in the foot than the leech is yards in depth. In large merchant-ships, the leech is four or five yards deeper than the main-topfail; but in smaller ships, only one or two cloths more in the foot than the leech is yards in depth.

The bunt is two-fifths of the depth of the leech; but in merchant-ships, it is from two-fifths to one-half of the depth.

Guns - - - -	110	98	80	74	50	44	38	36	24	18	16	Brig.
Tons - - - -	2165	1970	1900	1860	1200	1120	1040	920	600	425	360	200
Number of cloths { head -	26	25	25	25	21	20	19 $\frac{1}{2}$	19 $\frac{1}{2}$	17	15	14	12
in the - { foot -	28	27	27	27	23	22	21 $\frac{1}{2}$	21 $\frac{1}{2}$	19	17	16	13
Depth in yards { after-leech	26	25	25	25	21 $\frac{3}{4}$	21	20 $\frac{1}{2}$	20 $\frac{1}{2}$	18	16	15 $\frac{1}{2}$	11
of the - { fore-leech	10	9	9 $\frac{1}{2}$	9 $\frac{1}{2}$	8 $\frac{3}{4}$	8 $\frac{1}{2}$	8	8	7	6	5 $\frac{1}{2}$	5
Yards in the fail - -	486	442	448 $\frac{1}{2}$	448 $\frac{1}{2}$	335 $\frac{1}{2}$	309 $\frac{3}{4}$	292 $\frac{1}{4}$	292 $\frac{1}{4}$	234	176	157 $\frac{1}{2}$	106 $\frac{1}{4}$
Yards in the peek and } clue-pieces - - - }	3	3	3	3	3	3	3	3	3	3	3	3
Yards in the bunt-lining -	5	4 $\frac{1}{2}$	5	5	4 $\frac{1}{2}$	4	4	4	3 $\frac{1}{2}$	3	2 $\frac{3}{4}$	2 $\frac{1}{2}$
Totals -	494	449 $\frac{1}{2}$	456 $\frac{1}{2}$	456 $\frac{1}{2}$	343	316 $\frac{3}{4}$	299 $\frac{1}{8}$	299 $\frac{1}{8}$	240 $\frac{1}{2}$	182	163 $\frac{1}{4}$	111 $\frac{1}{4}$
Bolt-rope { head or stay -	3 $\frac{1}{2}$	3 $\frac{1}{2}$	3 $\frac{1}{2}$	3 $\frac{1}{2}$	2 $\frac{3}{4}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2	2	2
on the { foot - - -	2	2	2	2	1 $\frac{1}{4}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$
{ leeches - - -	2	2	2	2	1 $\frac{3}{4}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$

Gores.—Two cloths are generally gored on the bunt, and the head is gored 22 inches *per* cloth. If the nock-*seam* be subtracted from the depth of the leech, the remainder, divided by the number of cloths on the head, gives the depth of each gore.

Seams, tablings, cringles, &c. &c. as the mizen-stayfail.

MIZEN-TOPMAST-STAYSAIL, 9. *Plate IV. fig. 1.*

This sail is quadrilateral, cut square on the foot, and made of canvas N° 6, from 50 guns upwards; and N° 7, all under. It has a bunt, or fore-leech, three-sevenths or one-third of the depth of the after-leech, and is hoisted on the mizen-topmast-stay. The after-leech is one or two yards deeper than the mizen-topfail, and there are from two to five cloths more in the foot than the leech is yards in depth.

Guns - - - -	110	98	80	74	50	44	38	36	24	18	16
Tons - - - -	2165	1970	1900	1860	1200	1120	1040	920	600	425	360
Number of cloths { head -	20	19	19	19	15	13 $\frac{1}{2}$	13	13	11	9	9
in the - - { foot -	21	20	20	20	16	14 $\frac{1}{2}$	14	14	12	10	10
Depth in yards of { after-leech	16	14 $\frac{1}{2}$	16	15 $\frac{1}{2}$	13	12 $\frac{1}{2}$	12	12	10 $\frac{1}{2}$	9 $\frac{1}{2}$	9 $\frac{1}{2}$
the - - - { fore-leech	7	6 $\frac{1}{2}$	7	6 $\frac{1}{2}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$	4	4	3	3	3
Yards in the fail - - -	235 $\frac{3}{4}$	204 $\frac{3}{4}$	224 $\frac{1}{4}$	214 $\frac{1}{2}$	135 $\frac{1}{8}$	119	108	108	77 $\frac{1}{2}$	59 $\frac{1}{2}$	59 $\frac{1}{2}$
Yards in the peek and clue- } pieces - - - - }	3	3	3	3	3	3	3	3	3	3	3
Yards in the bunt-lining -	3 $\frac{1}{2}$	3 $\frac{1}{4}$	3 $\frac{1}{2}$	3 $\frac{1}{4}$	2 $\frac{1}{4}$	2 $\frac{1}{4}$	2	2	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$
Totals -	242 $\frac{1}{4}$	211	230 $\frac{3}{4}$	220 $\frac{3}{4}$	140 $\frac{1}{4}$	124 $\frac{1}{4}$	113	113	82 $\frac{1}{2}$	64	64
Bolt-rope on the { head	2 $\frac{3}{4}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{4}$	2 $\frac{1}{4}$	2 $\frac{1}{4}$	2 $\frac{1}{4}$	2	1 $\frac{3}{4}$	1 $\frac{3}{4}$
{ foot - - -	1 $\frac{3}{4}$	1 $\frac{3}{4}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$
{ leeches - - -	1 $\frac{3}{4}$	1 $\frac{3}{4}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$

Gores.—One cloth is generally gored on the bunt, and the head is gored 24 inches *per* cloth.
Seams, tablings, &c. &c. as the mizen-stayfail.

MIDDLE STAYSAIL, 3. *Plate IV. fig. 1.*

This sail is quadrilateral, cut square on the foot, and made of canvas N^o 6, from 50 guns and upwards; and N^o 7, all under. It has a square bunt, or fore-leech, five-twelfths of the depth of the after-leech, and is hoisted on the middle stay-fail-stay. The leech is from four to seven yards deeper than the main-topgallant-sail, and there are from six to eight cloths more in the foot than the after-leech is yards in depth. Sloops and brigs in the royal navy have only from one to three cloths more in the foot than yards in the depth of the after-leech. In merchant-ships, the leech is sometimes of the same depth as the main-topgallant-sail, but generally one to three yards more; and has from five to ten cloths more in the foot than yards in the depth of the after-leech.

Guns	-	-	-	-	110	98	80	74	50	44	38	36	24	18	16
Tons	-	-	-	-	2165	1970	1900	1860	1200	1120	1040	920	600	425	360
Number of cloths	{	head	-	25	24	24	24	24	20	19	18	18	16	14	13
in the		foot	-	25	24	24	24	24	20	19	18	18	16	14	13
Depth in yards	{	after-leech,	-	17	16½	16½	16½	13	13	12	12	12	10¾	10	10
of the		bunt or fore-leech	-	8	7½	7½	7½	5½	5½	5	5	5	4¼	4	4
Yards in the fail	-	-	-	312½	288	288	288	185	175¾	153	153	153	120	98	91
Yards in the clue and peek-	{	pieces	-	3	3	3	3	3	3	3	3	3	3	3	3
Yards in the bunt-lining		-	-	4	3¾	3¾	3¾	2¾	2¾	2½	2½	2½	2½	2	2
Totals	-	-	-	319½	294¾	294¾	294¾	190¾	181½	158½	158½	158½	125½	103	96
Bolt-rope on the	{	head or stay	-	3¼	3	3	3	2½	2½	2½	2½	2½	2	1¾	1¾
		foot	-	1¾	1¾	1¾	1¾	1½	1½	1½	1½	1½	1½	1½	1½
		leeches	-	1¾	1¾	1¾	1¾	1½	1½	1½	1½	1½	1½	1½	1½

Gores. The head is gored 13½ inches *per* cloth. *Seams, tablings, &c. &c.* as the above.

MAIN-TOPGALLANT-STAYSAIL, 4. *Plate IV. fig. 1.*

This sail is quadrilateral, cut square on the foot, and made of canvas N^o 7, from 50 guns and upwards, and all under of N^o 8. It has a bunt from one-third to three-sevenths of the depth of the after-leech, and is hoisted on the main-topgallant-stay-fail-stay. The after-leech is nearly of the same depth as the leech of the middle stay-fail, and there are from three to six cloths more in the foot than the leech is yards in depth. In merchant-ships there are from two to eight cloths more in the foot than the leech is yards in depth.

Guns	-	-	-	-	110	98	80	74	50	44	38	36	24	18	16
Tons	-	-	-	-	2165	1970	1900	1860	1200	1120	1040	920	600	425	360
Number of cloths	{	head or stay	-	22	21	21	21	17	16	15	15	15	13	12	12
in the		foot	-	22	21	21	21	17	16	15	15	15	13	12	12
Depth in yards	{	after-leech	-	16½	15½	15½	15½	13½	12½	12	12	12	10¼	9½	9½
of the		bunt or fore-leech	-	7	6	6½	6½	4½	4½	4	4	4	2¾	2½	2½
Yards in the fail	-	-	-	258½	225¾	231	231	153	136	120	120	120	84½	72	72
Yards in the clue and peek-	{	pieces	-	3	3	3	3	3	3	3	3	3	3	3	3
Yards in the bunt-lining		-	-	3½	3	3½	3½	2½	2½	2	2	2	1½	1½	1½
Totals	-	-	-	265	231¾	237¾	237¾	158½	141½	125	125	125	89	76½	76½

Gores.—The head is gored 24 inches *per* yard. *Seams, tablings, &c. &c.* as the mizen-stay-fail.

DRIVER-BOOMSAIL, 11. *Plate IV. fig. 1.*

This sail is quadrilateral, made of canvas N° 6, and is occasionally hoisted to the gaff in light fair winds. The fore-leech laces to the mizen-mast, and the inner part of the head to the gaff, and the outer part to a small yard.

The fore-leech is nearly the same depth as the fore-leech of the mizen-course, and the after-leech is from two to four yards deeper than the after-leech of the mizen-course.

Guns	110	98	80	74	50	44	38	36	24	18	16	
Tons	2165	1970	1900	1860	1200	1120	1040	920	600	425	360	
Number of cloths in the	{ head foot	25		26	25½	21	22½	22	19	16	15	14
		31		33	32½	27	28½	27	25	21	19	18
Depth in yards of	{ after-leech the - fore-leech	22½		24	24	19	23	23	22	18	16	16
		10		11	11	8½	11½	11½	11	8	8	7¾
Yards in the sail - - -		455	414½	515¾	507½	330	440	422½	363	222	204	189½
Yards in the clue-piece -		5	5	5	5	5	5	5	5	5	5	5
Yards in the tack, nock, and	{ peek-pieces - - - }	3	3	3	3	3	3	3	3	3	3	3
Yards in the gores - -		56	52	65½	63	47	53	47	36	26	20½	18
Totals -		519	474½	589¼	578½	385	501	477½	407	256	232½	215½
Inches.												
Bolt-rope on the	{ head foot leeches	1¾	1¾	1¾	1¾		1¾	1¾	1¾		1½	1½
		3	3	3	3		3	3	2½		2	2
		3	3	3	3		3	3	2½		2	2

Gores.—The head, foot, and mast-leech are cut with a roach or curve; and as no strict rule can be laid down, the gores must be judiciously increased or diminished, according to the sweep required. The gore on the head is at the rate of from nine to twelve inches *per* cloth; and on the foot from six to nine inches *per* cloth. From four to six cloths next the clue are cut square; or the fifth cloth next the clue being square, the other four cloths are short-gored, one inch *per* cloth to the clue. From four to six cloths are *gored* on the mast-leech; and if the depth of the leech be divided by the number of cloths in it, the quotient will be the regular gore *per* cloth, which must be increased on the middle cloths, so as to form the sweep required.

Seams are six inches broad for six feet up the sail from the foot; and two inches broad for four feet down from the head: the remainder is one inch broad. The seams are to

decrease gradually from one breadth to the other, but the selvage is not cut.

Tablings and head-holes, see second process in sail-making.

Clue-lining is five yards in length, and the *tack*, *nock*, and *peek-pieces* are each one yard in length.

Slack-cloth.—Two inches should be taken up with the rope in every yard on the mast-leech, and one inch in every cloth in the foot.

Iron thimbles are generally spliced in the rope at the tack, nock, and peek, which are otherwise fitted as the mizen-course.

Clue likewise is sometimes made with an iron thimble; but if not, it is made as described in the third process of sail-making.

Cringles for the lacing are made on the mast-leech, thirty inches asunder.

To find the quantity of canvas, refer to Rule 4.

MAIN-TOPMAST-STUDDING-SAILS, 19. *Plate IV. fig. 2.*

These sails are quadrilateral, and made of the same canvas as the lower studding-sails. They are spread beyond the leeches of the main-top-sail.

The depth is one yard more than the main-topfai!, and two cloths lefs are allowed for the breadth of the foot than the number of yards in the depth of the leech.

[illegible]

Gores.—Four cloths are gored on the outer leech in the royal navy, and from four to seven cloths in merchant-ships; and a regular gore is made on the head and foot of four inches *per* cloth, decreasing to the outer earing at the head, and increasing to the tack or outer clue at the foot.

For *frams, tablings, reef and head-holes*, refer to the second process of sail-making.

Reef-band is put on the same as the main-lower-fludding-sail.

Reef-cringle, one is made on the leeches, at each end of the reef-band, and a *downhaul-cringle* is made on the outer leech, about half the depth of the leech from the head.

Clue and sewing on the bolt-rope, refer to the third process in sail-making.

To find the quantity of canvas, refer to Rule 1

FORE-TOPMAST-STUDDING-SAILS, 16. *Plate IV. fig. 2.*

These sails are so much like the former, *reef-bands* excepted, as only to need the following dimensions.

[illegible]

MAIN-TOPGALLANT-STUDDING-SAILS, 20. *Plate IV. fig. 2.*

These sails are quadrilateral, and made of canvas N^o 7, from 50-gun ships upwards, and all under of N^o 8. They are spread beyond the leeches of the main-topgallant-sail, the heads being bent to their respective yards.

The depth is half a yard more than the main-topgallant-sail in large ships: there are five cloths more allowed for the breadth of the foot than the number of yards in the depth; but in small ships there are only three cloths more, or the same number of cloths in the breadth of the foot as yards in the depth of the leech.

Guns	110	98	80	74	50	44	38	36	24	18	16	Brig.	Cutter.
Tons	2165	1970	1900	1860	1200	1120	1040	920	600	425	360	200	180
Number of cloths in { head	12	11		11	8	8	8	8	6	5		6	5
the - - { foot	16	15	15	15	11	11	11	11	8	8		8	8
Depth in yards -	11	10 $\frac{1}{2}$	10 $\frac{1}{2}$	10 $\frac{1}{2}$	8	8 $\frac{3}{4}$	8 $\frac{3}{4}$	8 $\frac{1}{4}$	7 $\frac{1}{4}$	6 $\frac{3}{4}$	6 $\frac{1}{2}$	6 $\frac{1}{4}$	7
Yards in the sail	154	136 $\frac{1}{2}$	136 $\frac{1}{2}$	136 $\frac{1}{2}$	80 $\frac{1}{4}$	83 $\frac{1}{2}$	83 $\frac{1}{2}$	78 $\frac{1}{2}$	50 $\frac{1}{4}$	43 $\frac{1}{2}$	40 $\frac{1}{2}$	43 $\frac{1}{4}$	45 $\frac{1}{2}$
Bolt-rope on the {	Inches												
	head	1 $\frac{1}{4}$	1 $\frac{1}{4}$		1 $\frac{1}{4}$								
	foot	2	2		2	1 $\frac{1}{2}$	1 $\frac{1}{2}$		1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$
	leeches	2	2		2	1 $\frac{1}{2}$	1 $\frac{1}{2}$		1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$

Gores.—The outer leech is gored from two to four cloths, and a regular gore is made on the head and foot, from three to five inches *per* cloth, decreasing to the outer earing at the head, and increasing to the tack on the foot.

For *seams, tablings, and head-holes*, consult the first and second processes in sail-making.

Glues and sewing on the bolt-rope, see the third process in sail-making.

To find the quantity of canvas, refer to Rule 1.

FORE-TOPGALLANT-STUDDING-SAIL, 17. *Plate IV. fig. 2.*

This sail is so much like the former, that the dimensions need only be added.

Guns - - - -	110	98	80	74	50	44	38	36	24	18	16	Brig.
Tons - - - -	2165	1970	1900	1860	1200	1120	1040	920	600	425	360	200
Number of cloths in { head	11	10	10	10	7	7	7	7	5	4	4	6
the - - - { foot	15	14	14	14	10	10	10	10	7	7	7	8
Depth in yards - -	10	9 $\frac{1}{2}$	9 $\frac{1}{2}$	9 $\frac{1}{2}$	7 $\frac{3}{4}$	7 $\frac{3}{4}$	7 $\frac{3}{4}$	7 $\frac{1}{4}$	6 $\frac{1}{2}$	6 $\frac{1}{2}$	5 $\frac{3}{4}$	6 $\frac{1}{4}$
Yards in the sail - -	130	111	114	114	65 $\frac{1}{8}$	65 $\frac{1}{8}$	65 $\frac{1}{8}$	61 $\frac{1}{8}$	39	35 $\frac{1}{4}$	31 $\frac{1}{8}$	43 $\frac{3}{4}$
Bolt-rope the same size as the main-top-gallant-studding-sail.												

Number of Sails in a Suit for eight Months' Service in the Royal Navy.

Two main-courses.
Two main-topfails.
One main-topgallant-sail.
One main-royal.
Two fore-courses.
Two fore-topfails.
Two fore-topgallant-fails.
One fore-royal.
One spritfail-course.
One spritfail-topfail.
One driver-boom-sail.
Two mizen-courses.
Two mizen-topfails.
One mizen-topgallant-sail.
One main-stayfail.
Two fore-stayfails.

One mizen-stayfail.
Two main-topmast-stayfails.
One middle-stayfail.
One main-topgallant-stayfail.
One fore-topmast-stayfail.
One royal-stayfail.
Two jibs.
One flying-jib.
One mizen-topmast-stayfail.
Two main-studding-fails.
Two main-topmast-studding-fails.
Two main-topgallant-studding-fails.
Two fore-studding-fails.
Two fore-topmast-studding-fails.
One fore-topgallant-studding-sail.
One smoke-sail.

The Quality of Canvas of which the different Sails are made in the Merchant Service.

Canvas of N° 1.

Main and fore-courses, and main and fore-stayfais, of East India ships.

Canvas of N° 2.

Main and fore-courses, and main and fore-stayfais, of West India ships.

Canvas of N° 3.

Mizen-course, main and fore-topfais, sprit-course, and mizen-stayfais, of East India ships.

Canvas of N° 4.

Mizen-topfais of East India ships.

Canvas of N° 5.

Driver-boom-fais of large East India ships, main-topmast-stayfais of East India ships, and mizen-topfais of West India ships.

Canvas of N° 6.

Driver-boom-fais of East and West India ships, fore-top-mast-stayfais of East India ships, main-topmast-stayfais of West India ships, spritsail-topfais, and main and fore-top-gallant-fais, of large India ships.

Canvas of N° 7.

Main and fore-topgallant-fais, middle-stayfais, flying-jibs, lower fludding-fail, main-topmast-fludding-fais, main-topgallant-stayfail, of East and West India ships, and fore-topmast-stayfail of West India ships.

Canvas of N° 8.

Mizen-topgallant-fais, and main-topgallant-fludding-fais, of East and West India ships, mizen-topmast-stayfais and royals of East India ships, and small flying-jibs of East India ships, if any.

As there can be no fixed dimensions of merchant-ships' fails, the same number of cloths, or nearly so, of ships of the same tonnage in the royal navy may be taken, and about seven-eighths of their depth.

Quantity and Quality of Canvas of a single Suit of Sails for East and West India Ships of London Canvas, thirty-eight Yards to the Bolt.

		N° 1.	N° 2.	N° 3.	N° 4.	N° 5.	N° 6.	N° 7.	N° 8.	Total Number of Yards.
	Tons.	Yards.	Yards.	Yards.	Yards.	Yards.	Yards.	Yards.	Yards.	Yards.
East India ships of	1200	1373	—	1788	306	744	835	1331	496	6873
	700	952½	—	1291	262	270	436	1384½	285½	4881½
West India ships of	500	—	582½	714	—	151½	262½	1010½	130	2851
	400	—	446	615	—	156	297	847½	156	2517½

A Table of the Quantity of Materials used in making a Suit of Sails for a Ship of each Rate for eight Months' Service in the Royal Navy, and a single Suit of Sails for East and West India Ships.

		Old Canvas.	Twine Line.				Bee-Wax.	Rosin.	Turpentine.	Tallow.	Train-Oil.	Tar.	Spun-yarn.	Yards of Sewing Twine.		Bolt-rope.
			Extra, or fine.	Ordinary, or great.	Hambro.	Log.								Waxed.	Dipped.	
Royal Navy of	Guns.	Tons.	Yards.	Lb.	Lb.	No.	No.	Lb.	Lb.	Lb.	Gall.	Barr.	Cwt.			Cwt. qr. lb.
110		100	340	170	43	21	56	50	14	122	39	6½	5½	42164	21822	32 2 24
98			96	330	160	39	20	51	46	116	36	6	4½	39554	20631	28 3 26
80			96	336	165	42	21	56	48	121	36	6	5	41936	21018	29 0 21
74			96	330	165	42	21	56	48	121	36	6	5	41711	20671	28 3 24
50		70	250	120	37	17	40	36	10	90	21	3½	3½	31264	14908	16 3 21
44		70	246	118	36	16	39	34	10	88	20	3	3	31923	14150	14 3 22
38		65	238	114	36	16	38	34	10	86	18	3	3	31173	13913	14 1 9
36		57	228	114	35	16	38	34	10	84	18	3	2½	30197	13650	13 3 26
24		48	165	104	30	10	28	24	7	63	12	2	2	22475	10920	9 2 27
18		40	130	70	23	8	24	20	6	50	10	1½	1½	17836	9083	8 1 7
16		36	126	64	21	7	22	19	6	48	9	1½	1½	17240	8575	6 0 12
East India ships	-	1200	40	135	70	22	5			30	6	3	2½		41623	9 3 25
		700	30	107	60	20	4			26	5	2½	2		31395	7 0 12
West India ships	-	500	16	64	34	13	3			16	4	2	1½		22919	4 3 17
		400	12	60	30	9	2			13	3	1½	1½		20815	3 0 25

Brig's Mainsail.—This sail is quadrilateral, and made of canvas N^o 5 or 6. The fore-leech is in depth from the under part of the hounds of the main-mast to the boom, and the depth of the after-leech is about one-third more than the depth of the fore-leech. The head is bent to the gaff, and spreads within nine inches of the cleats on the outer end, the fore-leech to hoops encircling the mast; and the foot is spread on the boom within eighteen inches of the sheave-hole at the outer end.

Gores.—The head and mast-leech are gored with a roach. The regular gore on the head is from four to five inches *per* cloth, and the roach or sweep should be cut after the sail is sewed together. The foot is gored with a circular sweep, at the rate of five or seven inches *per* cloth, leaving four or five square cloths at the clue; or at the rate of fourteen to eighteen inches *per* cloth for every cloth in the mast-leech, which has five or six gored cloths in it.

Seams are three inches broad for eight feet up the sail from the foot, and two inches broad for eight feet down from the head; the remainder is one inch broad, the seams decreasing gradually from one breadth to the other.

For *tablings*, *head-holes*, and *holes* on mast or fore-leech, consult the first and second processes in sail-making.

Reef-bands.—This sail has three, six inches broad, parallel to the foot. The upper reef is nearly half way up the fore-leech, and the other at equal distances between that and the foot.

Reef-banks are generally sewed on the reef-band at each seam, on both sides of the sail.

Linings.—The after-leech is lined with one breadth of cloth from the clue to one yard above the upper reef-band; at the upper part half a yard of the lining is cut down, and the inner part is doubled under, or cut off. The peek-piece is one yard in length, and the fore-leech is lined with half a breadth of cloth; or sometimes pieces one yard in length are put on at the tack and nock, and small triangular pieces at each hole.

In sewing on the bolt-rope, four inches of slack-cloth should be taken up with the rope in every yard on the mast-leech.

Large iron thimbles are stuck in the cringles at the *clue*, *peek*, *nock*, and *tack*; also in the cringles made on the leeches at the ends of the reef-bands: a luff-crinkle is made on the mast-leech, equidistant from the lower reef-band and the foot, which also has a thimble.

To find the quantity of canvas, refer to Rule 4.

Cutter's mainsail only differs from the former in the following particulars, *viz.* the canvas is of N^o 1 or 2.

The *head* is generally wider, and the *peeks* less, for the customs, revenue, smuggling-cutters, and merchant service, than those of the royal navy. The former are better adapted for velocity, the latter for handsome appearance.

Reef bands.—To have four in number, eight inches broad, and put on parallel to the foot; the upper reef is about three-sevenths of the depth of the mast-leech from the foot, and the others equally divided between that and the foot.

The *seams* are five inches broad for twelve feet up the sail from the foot, and three inches broad for eight feet down from the head; the remainder to be one inch and a half broad.

Slack-cloth to be taken up in sewing on the bolt-rope is four or five inches in every yard in the depth of the mast-leech.

Smack's mainsail is similar to the above, and made of canvas N^o 1 or 2. The after-leech is about one-fifth deeper than the mast-leech.

Gores about ten cloths on the mast-leech. The head is

gored at the rate of four or five inches *per* cloth; and the foot, with a curve, at the rate of twelve or fourteen inches *per* cloth, for every cloth in the mast-leech, it having a short gore to the clue on five or six cloths, at the rate of three or four inches *per* cloth.

Linings.—The mast-leech is lined with a breadth of cloth from the tack to the nock; the after-leech the same as the brig, and the peek is lined with a cloth one yard and a half in length.

Reef-bands the same as the cutter; and sometimes a **Balance-reef** is put on across the sail, from the nock to the upper reef-crinkle on the after-leech.

Bolt-rope on the mast-leech should be three inches; and on the head, foot, and after-leech, one inch and a half; and four inches of slack-cloth should be taken up with the rope in every yard on the mast-leech.

Sloop's mainsail is like the smack's, but the after-leech is only one-third deeper than the mast-leech.

Cutter's Trysail.—This sail is occasionally used, instead of the main-sail, in stormy weather, and made of canvas N^o 1 or 2. In the head of this sail there are only two-fifths of the number of cloths that are in the head of the main-sail: the mast-leech is about three-fourths of the depth of the mast-leech of the main-sail, and the after-leech is one-sixth deeper than the mast-leech.

Gores.—Eight or ten cloths are gored on the mast-leech. The foot is gored with a curve at the rate of five or seven inches *per* cloth from the tack, leaving two or three square cloths at the clue.

Reef-bands.—This sail has three reef-bands, six inches wide, parallel with the foot, the upper one is three-eighths the depth of the mast-leech from the foot, and the others are at equal distances between the foot and the upper one.

Strengthening-bands.—Three are put on, of half a breadth of cloth, at equal distances between the upper reef-band and the head, which are seamed on and stuck along the middle.

Seams should be five inches broad for twelve feet up from the foot, and three inches broad for eight feet down from the head; the remainder is one inch and a half broad, to decrease gradually from one breadth to the other.

Linings, tablings, reef-banks, &c. &c. as the main-sail.

Vessels having one mast only, have sails peculiar to that class, which we shall briefly notice. Such are the

Square Sail, or Cross-Jack.—This sail is quadrilateral, made of canvas N^o 6 or 7, cut square on the head and leeches: the head is bent to the cross-jack yard, and extends within six inches of the cleats on the yard arms. The depth of the sail is about four-fifths of the depth of the fore-leech of the main-sail.

Gores.—The foot is gored one inch or more *per* cloth, increasing from the middle to each clue; having two or three square cloths left in the middle.

Seams, tablings, and head-holes, as other sails of the same size.

Reef-bands.—It has two, four inches broad; the lower one is at one-sixth of the depth of the sail from the foot, and parallel thereto; and the upper reef is at the same distance from the head.

Reef-banks are sewed on the reef-bands, as on the main-sail.

Linings.—One yard of cloth is put on at each clue, half a yard at each earing, and half a yard against every cringle on the leeches. These linings are all put on the aft-side.

Crinkle.—One is made at each end of the upper reef-band; and three bowline-crinkles are made on each leech; the upper

bowline-cringle is made on the middle of the leech, and the others are equally distant from that and the clue.

Clues are sometimes marled on; and, for this purpose, ten marine-holes are made each way from the clues.

Bolt-rope on the foot and leeches, should be one inch and a half or two inches in circumference; and on the head, one inch, or one inch and a half.

Slack-cloth, when sewing on the bolt-rope, one inch should be taken up in every cloth in the head and foot.

Top-sail is similar to other top-sails made of canvas N° 6 or 7. The depth in the middle is one-third of the depth of the cross-jack.

Gores.—From one to two cloths are gored on the leeches, and the foot is hollowed from one-third to half of the depth of the sail in the middle (to clear the jib-stay), or at the rate of ten to twelve inches *per* cloth from the middle to each clue, the middle cloth being left square.

Reef-band of four inches broad is put on at one-third of the depth of the middle cloth from the Lead.

Bowline, cringles, &c. &c. as the square sail.

Gaff-top-sail.—This sail is quadrilateral, and made of canvas N° 8. The fore-leech is four-fifths of the depth of the mast-leech of the main-sail. This sail is bent to the top-gall-mast, with a small yard on the head above the main-sail, and is only used in light winds.

The foot has nearly the same number of cloths as in the head of the main-sail, and nearly three-fourths of the number of cloths are gored on the mast-leech.

Gores at the foot are the same as the gores on the head of the main-sail, that the foot may answer to the peak of the main-sail, the head-gores being the same.

Bolt-rope on the mast-leech should be one inch and a half; and on the head and foot and after-leech, one inch.

Saveall-top-sail.—This sail is quadrilateral, made of canvas N° 8, cut square on the head and foot. The head is extended by haliards fastened to the earing-cringles, under the hollow of the foot of the top-sail, its foot spreading the cross-jack yard between the clues of the top-sail. It is seldom used but in light winds.

Gores.—Two or three cloths are left square on the head, and the rest are gored for the leeches.

Bolt-rope round the sail is one inch in circumference.

Ringtail-sail.—This sail is quadrilateral, made of canvas N° 7 or 8. It is occasionally hoisted abaft the after-leech of the main-sail, to which the fore-leech is made to answer. The head is bent to a small yard at the outer end of the gaff; and the foot on the boom, which is prolonged by a piece lashed to the outer end. The number of cloths in the foot is three-eighths the number of cloths in the foot of the main-sail; and the head has three-eighths of the number of cloths in the foot.

Gores.—The head has a regular gore, the same as the main-sail, and the foot is gored with a gore of one inch *per* cloth, increasing to the tack.

Bolt-rope on the head, foot, and after-leech, should be one inch in circumference; and on the fore-leech one inch and a half.

A sail of this kind, but more square, is sometimes spread in light winds, on a small mast, erected at the taffarel of some vessels; the foot being spread out on a boom that projects horizontally from the stern.

Fore-sail.—This sail is triangular, made of canvas N° 1 or 2; and bends with hanks to the stay next before the mast. The depth of the leech is nearly the same depth as the mast-leech of the main-sail, and there are as many cloths in the foot as will bring it clear of the mast.

Gores.—The depth of the hoist, or fore-part, divided by

the number of gored cloths, gives the length of each gore. The foot has a short gore of one inch or more *per* cloth, increasing to the clue; leaving one or two square cloths at the tack.

Linings, &c.—The leech-cloth is left three-quarters of a yard longer than the depth of the leech for the head-lining, and the cloth at the tack is so cut as to fall to the foot and form its own lining; it has one cloth at the clue, to run up above the reef-bands, the same as the main-sail.

Seams should be three or four inches broad at the foot, decreasing to one inch at the hoist.

Reef-bands.—To have two four inches wide, are generally put on at one-eighth of the depth of the sail *afunder*, the lower one being at that distance from the foot. Sometimes a bonnet is used instead of the lower reef.

Reef-banks are generally sewed on, instead of using reef-points.

Bolt-rope on the stay to be two and a half or three inches in circumference, and on the foot and leech one inch and a half or two inches.

Slack-cloth.—Three or four inches of slack-cloth should be taken up with the rope in every yard on the hoist.

Head-stick.—The hoist-rope is put through the holes in the head-stick, then served with spun-yarn, and spliced into the leech-rope. The middle of the head-stick is then seized to the head of the sail, and a thimble is seized in the bight of the rope.

Thimbles are generally stuck in the cringles at the tack and clue.

Jib.—This sail is triangular, made of canvas N° 2 to 6, and is sometimes bent with hanks to a stay before the fore-sail, or hoists with bahards without a stay. The number of cloths in the foot is two-thirds the number in the foot of the main-sail, or wide enough to spread the bowsprit, and the depth of the leech is about one yard for every cloth in the foot.

Gores.—The foot is gored with a sweep, at the rate of from four, five, to six inches *per* cloth, increasing to the clue, leaving one square cloth at the tack; sometimes the fourth and fifth cloths from the tack are left square, and a short gore from thence to the tack of one inch *per* cloth.

Linings.—The leech-cloth is left three-quarters of a yard longer than the depth of the leech, for the head-lining and tabling; the cloth at the tack is cut so as to fall to the foot and form its own lining; and the clue-piece is two yards in length.

Seams on the foot should be three or four inches broad, and should decrease to one full inch on the hoist.

Bolt-rope, if hoisted on a stay, the rope on the hoist should be two inches and a half or three inches in circumference; but if not hoisted on a stay, the rope on the hoist should be five inches. The rope on the foot and leeches should be two inches and a half.

Slack-cloth.—Four or five inches of slack-cloth should be taken up in every yard in the hoist, when roping, and the rope on the hoist put through the holes in the head-stick, and completed as the fore-sail.

Observe, the *second jib* is seven-eighths the size of the *first jib*, and the *third jib* is three-fourths the size of the *first jib*; but they are both made like the *first jib*, as above.

Storm Jib.—This sail is triangular, and made of canvas N° 1 or 2. It is two-thirds the size of the first jib, and is used in stormy weather.

Gores.—The foot is gored at the rate of five or six inches *per* cloth, increasing to the clue.

Seams.—To be three or four inches broad at the foot, and decreased to one inch on the hoist.

Lining.—The clue is lined with a breadth of cloth one yard and a half in length; a piece one yard long is put on the peek, and the cloth at the tack is so cut as to fall to the foot, and form its own lining.

Strengthening-bands, of half a breadth of cloth, are put on parallel to the foot, at one-third of the depth of the sail afunder.

Bolt-rope on the hoist should be five inches in circumference, and on the foot and leech two inches and a half.

Slack-cloth.—Four inches of slack-cloth should be taken up in every yard on the hoist when roping.

Flying Jib.—This sail is triangular, made of canvas N° 6, and is two-thirds the size of the *first jib*. It is the foremoft sail, and hoists without a stay.

Gores.—The foot is gored with a sweep, at the rate of eight or nine inches *per* cloth, increasing to the clue.

The *piece* at the *clue* is one yard and a half in length; that at the *peek* is one yard; and the cloth at the tack is so cut as to fall to the foot.

Seams should be two inches and a half broad at the foot, and decrease to one inch at the hoist.

Bolt-rope on the hoist should be three inches and a half in circumference; on the foot two inches, and on the leech one inch.

Slack-cloth.—Three inches of slack-cloth should be taken up with the rope in every yard in the hoist.

Thimbles are sometimes spliced in the tack and peek.

Boat Sails.

Settee-sail.—This sail is quadrilateral, made of canvas N° 7 or 8. The head is bent to the latteen-yard, and extends within six inches of the cleats at the arms.

Gores.—The cloth at the tack is cut goring to the nock, and the bunt is the depth of the reef, which is one-fifth of the depth of the leech. The depth of the leech is five-sixths of the length of the head. The length of the head, divided by the number of cloths in it, gives the length of each gore. The foot is cut with a curve, after the sail is sewed together.

Head-holes and *reef-banks* as other sails, with small *cringles* made on the leech at the *reef*, *nock*, and *peek*.

Lug-sail.—This sail is quadrilateral, made of canvas N° 7 or 8. The head is bent to a yard, and extends within four inches of the arm-cleats. The fore-leech is as deep as the length of the head, and the after-leech is nearly one-half more in depth than the fore-leech.

Gores.—Two or three cloths are gored on the fore-leech, and an even gore of six inches *per* cloth is made on the head. The foot is gored with a curve; the cloth at the clue being cut with a three-inch short gore; the next cloth is square, and the cloths from thence to the tack are gored at the rate of six or eight inches *per* cloth.

Reefs.—Two in number parallel to the foot; the upper reef is half way up the fore-leech, and the other is equally

distant from that and the foot. Sometimes *reef-bands*, three or four inches broad, are put on at the reefs; but when these are not used, holes are made one in every seam, for *points* or *hanks* are sewed on instead.

Holes.—Two small ones are made in each cloth in the head.

Cringles are made on the leeches at each reef; *earing-cringles* are made at the nock and peek; and ten or twelve strands in the length of the bolt-rope are seized at the tack and clue.

Latteen-sail.—This sail is triangular, made of canvas N° 7 or 8. The head is bent to the latteen-yard, extending within six inches of the cleats at the arms.

Gores.—The length of the head, divided by the number of cloths, gives the length of the gore of each cloth. The foot is cut square.

Two small *holes* are made in each cloth along the head, through which it is laced on the yard.

Bolt-rope for this and the two foregoing sails are alike; that is, one inch on the head, and one inch and a half on the foot and leeches.

Observe, if this sail is bent to the mast the head becomes the fore-leech, and it is called a *shoulder-of-mutton sail*. But if to the mast and a top-mast, which slides up and down, a *sliding-gunter sail*.

Sprit-sails.—These sails are quadrilateral, made of canvas N° 7 or 8. The fore-leeches are laced to their respective masts; and their heads are elevated and extended by a sprit, or small yard, that crosses the sail diagonally from the lower part of the mast to the peek.

The *fore-leech* is nearly the depth of the mast, so as to clear the gunwale a few inches.

Gores.—The main and fore sprit-sails have one or two cloths gored at the fore-leech. The heads of them have a regular gore of twelve or fourteen inches *per* cloth, and the foot is cut square. The fore-leech and foot of a mizen-sprit-sail are cut square, but the head has a regular gore of eleven inches *per* cloth.

Holes are made on the fore-leeches about one yard afunder for lacing them to the mast, and the mizen three-quarters of a yard. Holes are also made at each seam across the sail of main and fore for a reef, at one-fifth the depth of the after-leech from the foot for the points or reef-hanks, instead of being sewed to the sail.

Small bights are made at the tack, nock, peek, and clue.

Fore-sail and Jib.—Proportionally the same as the last mentioned.

SAIL-Loft, a room or shed wherein sails are made.

SAIL-Room, in *Ship-Building*, an apartment or place of reserve, built between decks, upon the lower deck or orlop, to contain the spare sails.

SAILS also denote the vanes of wind-mills; or the arms or flights, by which the wind has its effect on them.

These are either horizontal or perpendicular. See *WIND-MILL*.

Salt

SALT, **SAL**, in *Chemistry*, is a term so variously applied as not to admit of an accurate definition. It is observed, however, that the general and the most ancient idea of a salt is, a crystallizable substance, considerably soluble in water, and highly sapid; but for the sense in which the term is at present applied, or of acids with alkalies, earths, or metallic oxyds, see **SALTS**. See also the references under **SAL**, and **Rock-Salt**.

SALT, in the *Manufactures* and *Domestic Economy*, generally signifies the common culinary salt, which in a state of purity is called muriate of soda. See *Muriate of Soda*, under **SODA**.

Under this head we shall give an account of the different varieties of the common culinary salt, and describe the different processes by which it is manufactured.

Alimentary or common salt may also be distinguished into various kinds, according to the various ways of preparing it. Hence we have,

1. *Bay-salt*, prepared by evaporation, by the heat of the sun. This salt is of two kinds; the first drawn from sea-water, as is practised in France, Spain, and Portugal, and many other hot countries; the other from the water of salt-springs, or lakes, as in the Cape Verd islands, in the island of Tortuga, Turk's island, and many parts of America. The first kind, in time of peace, is imported into Great Britain in large quantities. America and its fisheries are commonly supplied with the latter.

The several kinds of bay-salt made in the different parts of the world are found to differ greatly from one another in several particulars; as, 1. In the size of the crystals, which is owing to the heat of the sun, and the time it lies in the pits. The French cream of salt, and the blown salt of the isle of May, are fine and small-grained. The Portugal salt is larger grained than that of France; and that of Tortuga is larger than either. 2. In purity: as all bay-salt has some mud, slime, or the like, in the making, and some kinds are mixed with the bittern salt, or what is called Ep-som salt. 3. They are all more white while dry, and more pellucid when moist; and they differ in colour, according to the earth which makes the bottoms of the pits. Thus, some of the French bay-salt is grey, some reddish, and some white, according as a blue clay has lined the pits, or a red or white one. 4. Some kinds of bay-salt are more apt to contract a moisture from the air than others: an imperfection to which the common sorts of marine salt are much more subject: this is sometimes owing to the smallness of the grain, and sometimes to a mixture of a calcareous or alkaline salt with it, or to a combination of earth with marine acid. And, 5. Some kinds have an agreeable smell in large heaps; such are the Portugal, and the Hampshire bay-salts; and this seems owing to the sea-water they were made from having a bituminous matter in it. 6. It differs greatly in taste, according to the various foreign mixtures it

contains; and it will often alter in taste, and other qualities, by long keeping. Thus the salt of Peccais is so bitter, when new made, as not to be eatable, but after keeping a while, it becomes very pleasant. This is owing to its containing at first a large proportion of the bittern salt, or Ep-som salt, which liquefies in keeping, and running off in form of a fluid, leaves the rest of a good taste. In general, bay-salt is much fitter for use after it has been kept some time in a dry place, than when it is first made.

2. *Marine salt* boiled, which is extracted from sea-water by coction.

3. *Brine salt*, or fountain salt, prepared by boiling from natural brine, whether of ponds and fountains, or of lakes and rivers.

4. *White salt*, prepared from sea-water, or any other kind of salt-water, first heightened into a strong brine by the heat of the sun, and operation of the air.

5. *White salt*, prepared from a strong brine, or lixivium drawn from earth, stones, or sands, strongly impregnated with common salt.

6. Refined rock-salt, which is boiled from a solution of fossil salt in salt-water, or in fresh. And,

7. *Salt upon salt*, which is made from bay-salt dissolved in sea-water, or other water, and boiled to a white salt.

All these kinds, except the first, are comprehended by Dr. Brownrigg under the general denomination of *white salt*.

There is no soluble salt found in nature so abundant as the salt under consideration. We find it in some proportion in almost every animal and vegetable substance. In the earth it is found in vast masses, constituting rocks of such extent, as to afford an exhaustless source of this valuable ingredient of our food. The most remarkable of the salt-mines, which are excavations made into these rocks, are at Wilieeska in Poland, Catalonia in Spain, Altemonte in Calabria, Loowur in Hungary, Tunis in Algiers, and Cheshire, in this country. Sources of a similar kind have also been discovered in America. These rocks are sometimes almost pure salt, requiring merely to be reduced to powder. In others it abounds with earthy matter, and sometimes with oxyd of iron, giving it various colours. The fossil salt of Cheshire is of the latter kind, and requires to be dissolved in water, and evaporated, to obtain it in crystals. See **Rock-Salt**.

Salt-springs are another source of salt, and some lakes abound with a considerable quantity. The sea itself is the principal of this class, which would furnish a sufficient supply for the use of man, if no other source of it existed. Indeed, the circumstance of the sea abounding with more of this ingredient than any other, is a sufficient proof of what we have before asserted, that it is the most plentiful soluble substance in nature. The water of the sea, which raised in the state of pure water, and afterwards filtering through the earth

and mountains, brings to that immense reservoir every thing soluble which it finds in its way. Hence we find many other substances besides salt in sea-water. This will be exhibited in a tabular form hereafter. The salt-works of Wieliczka, in Poland, are upon an immense scale. The subterraneous excavations extend upwards of three miles. Dwellings and chapels are formed in the solid rock, having the appearance of enchantment. The number of people employed are from twelve hundred to two thousand. They are said not to live long, being liable to a complaint in the chest. Great quantities of this salt require merely to be pulverized.

In Cheshire, particularly in the neighbourhood of Northwich, the salt-works are very extensive. Great quantities are got in the solid form, but not sufficiently pure for use. In this state it is conveyed from the mines to the Cheshire side of the river, nearly opposite to Liverpool. It is at this place dissolved in the sea-water, from which it is afterwards separated by evaporation and crystallization, by a process which we shall describe.

There are also in the same district salt-works, at which the salt called Cheshire salt is extracted from brine. These works are described very intelligibly by Dr. Holland, in the Report of Agriculture for the County of Cheshire. See *Rock-Salt*.

We shall give a brief account of the process employed here for extracting the salt, for the facts of which we are indebted to the above author. The different states in which this salt is sold has given it different appellations, which are, *flowed* or *lump salt*, *common salt*, and another variety in the form of large crystals, called *fishery salt*. In making the first, the brine is put into pans of great surface and little depth, made of wrought iron, after the manner of steam-engine boilers. The fire being made to play uniformly over the bottom, the brine, which is fully saturated, is raised to the temperature of 226° . This high temperature, which is 14° above the boiling point of water, is induced by the presence of the salt. As soon as the liquid is hot, a white powder, sometimes tinged with oxyd of iron, becomes separated. This is partly skimmed off, and some falls to the bottom of the pan. This is mostly carbonates of lime and iron, which were dissolved in an excess of carbonic acid, and which is driven off when the heat is applied. It may here be remarked, that the stratum of red marl in which the salt veins are found, contain carbonate of lime; and it is so liable to contain that excess of carbonic acid by which it becomes soluble, that the springs of those countries where the same red marl abounds, are highly charged with carbonate of lime, which is precipitated by heat. The removal of the carbonates above-mentioned from the brine, as well from the surface as from the bottom, is called clearing the pan. Some brines abound with this impurity more than others, and some contain none at all. The liquid now becomes clear, and crystals of salt form on the surface till they fall, by their accumulating gravity, in the space of from eight to twelve hours. The principal part of the water is evaporated; the salt is now taken out with wooden shovels, and put into conical baskets, called *barrows*, from which the liquid part may drain. The salt is then dried in a stove, where it loses about one-seventh of its weight, and assumes the lumpy form, from which it takes its name.

After the pan has been used for a few weeks, the bottom becomes coated with the precipitates above-mentioned to a considerable thickness. These require to be removed by mechanical means, being almost as compact as stone. It would be an advantage to remove this substance oftener. It

not only loses time by protracting the process, but the bottom of the pan becomes heated so hot as soon to be destroyed by the action of the air.

The *common salt* is made by the same process, but it is not flowed after draining, and the evaporation is conducted more slowly, the temperature being from 160° to 170° .

The *fishery salt* is made by the same apparatus, and from the same brine, but the evaporation is still slower than the last, the temperature being only from 100° to 110° , and the process lasts from seven to ten days. By this means the crystals become much larger and harder, and hence are better adapted for the use of fisheries. All these varieties of salt, and many others, have been analysed by Dr. Henry of Manchester; an account of which has been published in the *Philosophical Transactions* for 1810. We shall in the sequel to this article give a table of the principal facts, with other judicious remarks, given by this celebrated chemist.

The salt-springs of Namptwich, in the same county, and Droitwich in Worcestershire, are evaporated by a process similar to that above described. The salt which they afford is held in high estimation for its great whiteness.

Before we quit the subject of the Cheshire salt, it will be proper to point out the advantage derived from sending the rock-salt to the sea-coast to be manufactured. The sea-water, in which it is there dissolved, being saturated with salt, 100 tons of this brine afford 23 tons of salt; the same quantity of sea-water affording 2 tons 27 cwt. which would require the same quantity of fuel to evaporate it. See *SALT-Brine Springs*.

Considerable salt-works are carried on in Scotland, and in the northern counties of this country on the sea-coast, by the evaporation of sea-water. At Lymington, in Hampshire, the sea-water is evaporated to one-sixth of the whole by the action of the sun and air.

The works in which the sea-water is heightened into brine are called *sun-works*, or *out-works*. These are constructed on a flat down or oozy beach: within a mole, which is raised, if necessary, to keep out the sea, there is a large reservoir, or feeding pond, communicating with the sea by a sluice, and adjoining to this reservoir a long trench, parallel to which there are several square ponds, called *brine-pots*, nine or sometimes twelve placed in a row, and parallel to this two other rows of the same kind; beyond the third row there is a row of larger ponds, three in number, called *sun-pans*, with each of which three or four of the *brine-pits* in the third row communicate by narrow openings; and these often communicate with a larger pond, called the *common sun-pan*, from which the brine flows into large covered cisterns (made very tight of brick and clay) adjoining to the boiling-house. The bottoms of the ponds are in several places formed of an oozy mud, well trodden and laid smooth; and in the *brine-pits* and *sun-pans* covered with sea-sand. The bottoms of all the pits form an inclined plane, highest at the reservoirs, and lowest at the common sun-pan. The partitions between the ponds are of mud and earth, about two feet broad, with little openings, by which the pits communicate with one another. The sea-water, received at full sea into the reservoir, is thence let out, as occasion requires, into the trench, and from the trench into the first row of *brine-pits*; and when they are duly filled, the openings between them and the trench are closed with mud. The water, after standing for some time in these pits, is let out into the second row; and after a certain time, according to the degree of evaporation, into the third row of pits; those of the first row being again filled; and thus they are filled and emptied alternately. When the brine is sufficiently evaporated in the third row of *brine-pits*, it is suffered to flow

into the common sun-pan, where its weight is examined by glass hydrometers; and being found of due strength, it is drawn from thence into the cisterns, where it remains till they are ready for boiling it. The sea-water, thus carried through the whole work, is called a course of brine; and in hot weather, it acquires its proper strength in twenty-four hours; but, if showers approach, it is drawn into the cistern before it is brought to its full strength. In this course the salt-water stands deepest in the pits of the first row, and is gradually shallower in the others, till it arrives at the sun-pan, where it is shallowest, and in the common sun-pan it is somewhat deeper, being about six or seven inches deep. After this manner, if the season proves favourable, they make as much brine as keeps them boiling till near Christmas; after which they repair their pans and furnaces; and prepare their Epsom salt from the bittern, and begin again to make brine about April.

The next operation is performed by artificial evaporation, in boilers similar to those used in other salt-works. The pans in which they boil the salt at Lymington are of lead, of a square form, and smaller than those used for boiling sea-water into salt. They have usually four of these in a saltern, placed in a row, with a furnace to each of them. The chimnies are carried up by the side of the wall, which divides the boiling-house from the fire-house; and the smoke is conveyed from each furnace into these chimnies by two flues, one on each side of the mouth of the furnace. To each of these flues is fitted a register, or plate of iron, placed horizontally, which may be drawn out, or thrust in over the flue so as to close it, and prevent the smoke from ascending through it; and by means of these registers and vent-holes, and doors to the mouths of the furnaces and ash-pits, they are able to regulate the fires in the exactest manner, and damp them while the salt is graining, or smother them quite out, if they find occasion. In the boiling-house they have a chimney to convey off the vapours from each pan; which is a square funnel of boards. There is only one long walk in the boiling-house, on the side of the pans opposite to the mouths of the furnaces, and between this walk and the wall are placed large wooden troughs, with several little holes at their bottoms; into which troughs the salt, when drawn out of the pans, is put to be drained from the bittern.

The process varies, in some degree, from that used in Cheshire. The salt is not removed from the boiler till the whole of the water is evaporated. It is then taken out all at once, and placed in troughs with holes in the bottom. A certain quantity of moist uncrystallizable matter adheres to this salt, which drains through the above-mentioned holes into pits below. Immediately under the holes are placed upright stakes or pillars, down which the liquid runs, and upon which a portion of salt crystallizes in masses, which in ten or twelve days weigh as much as 60 or 80 lbs. These masses are called *salt-cats*, and amount to $\frac{1}{10}$ th of the whole salt manufactured here. The liquid which passes into the pit is of a very sharp bitter taste, and is called *bittern*. It is reserved for the winter season, when the salt-works are suspended, and then undergoes evaporation to a certain extent. A little more common salt is separated, which is reserved to add to the salt-brine. The evaporated fluid is placed in wooden coolers, eight feet long, five feet broad, and one foot deep, where it affords crystals of Epsom salt (sulphate of magnesia). The remaining liquid is drained off from the crystals, and runs away. This is called single Epsom salt, to distinguish it from the same article, after a second solution and crystallization, which is termed double Epsom salt. Four or five tons of Epsom salt are pro-

duced from a quantity of sea-water which has yielded two of common salt and one of cat-salt. We are indebted to Dr. Henry's essay above alluded to for the account of these salt-works, who had it from a gentleman residing at that place.

The artificial method of promoting the evaporation of sea-water, and the preserving the brine in the English salt-pits from being diluted with rain, proposed by Dr. Brownrigg, is as follows. A number of salt-pits should be made in a row in the marsh, from east to west, and their bottoms lined with plaister, or some strong cement that will not easily break up; and by this caution, the salt may be drawn white and pure like the Portugal kind, not grey like the French. Over each pit covers should be made of thin boards, or rather of canvas painted white, and stretched on frames of wood, and these should be fixed to strong posts, erected on the north side of the pits, and contrived to be easily drawn back to them, in the manner of drawbridges. These covers, thus fixed, may be let down over the pits in the manner of a shed or pent-house, in rainy weather, to keep the brine from being diluted with fresh water; and in dry weather they may be raised almost to a perpendicular, but inclining a little towards the south, so as to form a wall with the south aspect; and thus they would serve for a double use, being a covering to the pits in rainy weather, and reflectors of the sun's heat in dry weather. The reflection of so large a body of the sun's rays, in the course of a bright day, would greatly promote the evaporation of the brine; and the hinges on which the reflectors turn, being placed at ten inches from the ground, when the reflectors stand upright, there will be a space under them, through which the air will continually flow in a brisk current, and this will greatly promote the evaporation of the water.

The passages of communication between the pits must be narrow and winding, and must be wholly stopped up in wet weather, that no fresh water run into the brine. This channel should be covered also with boards, and, at the entrance of the pits, there must not be a pond, as is the custom in France, but only a narrow covered trench, running parallel with the side of the pits, which is opposite to the reflectors; and the pond, which forms the entrance of the pits in the French salt-marshes, must in these be detached from them, and instead of it, there must be formed a fourth brine-pond, communicating with the third by a long and narrow channel.

If these contrivances should be reduced to practice in England, the salt will probably crystallize much faster there than in the French marshes, and the brine may be kept as deep, and even deeper than in the French pits; and a shower of rain will only retard the work for the small time in which it is falling; whereas, in the French works, it throws them back three or four days, as no salt can be formed till all the water it brought be evaporated.

Four cisterns may be dug adjoining to the brine-pits, to admit the brine in the salt-ponds, when the weather is very rainy; and as to the salt-water in the reservoir, if it should be found necessary to preserve it from rain in cisterns, when so much rain falls as to make it fresher than sea-water, it may be let out, and sea-water admitted in its place. And, in order to promote the evaporation, and to make the salt-water in the reservoir fitter to supply the first brine-pond with brine of a due strength, it may be proper, by means of a small fire-engine, continually to force up the salt-water in the reservoir, as often as occasion requires, and, by means of a diverger, fitted to the engine, to make it descend again into the reservoir like a shower of rain: by which means, the evaporation of the watery vapours will be greatly pro-

moted after much the same manner as is practised at several of the salt-works in Germany, where the brine is very weak.

Thus by augmenting the force of the sun's heat, and of the air, by promoting the evaporation of the watery vapours, and preventing the brine from being diluted with rain, it is very probable that, during the summer season, double the quantity of salt might be prepared at an English work with these contrivances, that is now usually prepared at a French salt-marsh of equal magnitude.

Besides these methods of managing sea-water, it is certain that very large quantities of bay-salt might be prepared in England with great ease, from the natural brine of salt-springs, and from the common fossil or rock-salt of Cheshire, dissolved in weak brine, or in sea-water. Upon the whole, the bay-salt might thus be made here at a moderate price, and in sufficient quantities to supply both the nation itself, and all our colonies.

Dr. Watson, in his *Chemical Essays*, vol. ii. p. 58, having found, by experiment, that, in a summer-day of sixteen hours, three gallons of water may be dispersed into the air, by a warm sun and a brisk wind, from the surface of a linen cloth, equal to one square yard, suggests a method of manufacturing bay-salt, by wetting and drying alternately any number of square yards of coarse cloth: and he observes, that one labourer, assisted by proper mechanical contrivances, might be equal to the daily management of a thousand yards, or more. By this plan in favourable weather there would be daily evaporated twenty-four thousand pounds of water, which, supposing sea-water to contain one thirty-second part of its weight of salt, would give seven hundred and fifty pounds of salt.

He adds, that those who have seen the artifice of strengthening brine, which is practised in Franche Comté, and other places, by making it drip through taggots, in order to increase the evaporation, by increasing the surface of the water, which is exposed to the air, will not be surprized at this method of evaporating water.

Marine salt is prepared by boiling sea-water. This salt is only made in countries where great quantity of fuel can be had at a very low price, or where the sun has not force enough; and is therefore made in few counties of England, except on those parts of the British coast which most abound in pit-coal. This has thence got the name of *Newcastle salt*.

The salt-works in the north are the most extensive, and are wholly carried on by artificial heat.

The most convenient works for the manufacture of this salt are constructed in the following manner. The saltern is erected at some convenient place near the shore; it is a long and low building, consisting of two parts, one called the fore-house, and the other the pan-house, or boiling-house. The fore-house serves to receive the fuel, and cover the workmen; and in the boiling-house are placed the furnace, and the pan or boiler in which the salt is made. And in some places they have two pans, one at each end of the building, and the fuel and place for the workmen are in the middle. The furnace opens into the fore-house by two mouths, and from these is carried up a wall to prevent the ashes from flying to the salt-pans, and in this is a door of communication between the two houses. The body of the furnace consists of two chambers, divided from one another by a brick-work, called the *mid-feather*, which from a broad base terminates in a high edge nigh the top of the furnace, and by means of short pillars of cast-iron fixed upon it, supports the salt-pan. The pans are oblong and shallow, the common measure being fifteen feet in length, twelve feet in breadth, and sixteen inches in depth; they

are commonly made of plates of wrought iron, joined together with nails, and the joints filled with a strong cement; and the bottom of the pan is prevented from bending down, or changing its figure, by hooks fastened to strong iron-bars which are placed across it. Sometimes the sides, which are not always covered with liquid but exposed to the air, are made of lead, iron being liable to be corroded.

Between the sides of the pan and the walls of the boiling-house there runs a walk, five or six feet broad, where the workmen stand to draw out the salt. The roofs are wood, and are fastened with pegs of wood, nails mouldering away into rust in a few months.

Not far distant from the saltern on the sea-shore, between full sea and low-water mark, they make a little pond in the rocks, or with stones in the sand; this they call a *lump*; and from this pond they lay a pipe, through which, when the sea is in, the water runs into a well adjoining to the saltern, and by this well they pump it into troughs, by which it is conveyed into their ship or cistern, in which it is stored up till they have occasion to use it.

The cistern is built close to the saltern, and may be placed most conveniently between the boiling-houses on the back side of the fore-house. It is made either of wood, brick, or clay, and should be covered with a shed, that the salt-water in it may not be weakened by rains, and should be placed so high that the water may conveniently run out of it into the pans. When the sea-water has stood in the cistern till the mud and sand are settled from it, it is drawn off into the salt-pan; and at the four corners of the salt-pan, where it is supported by the brick-work, and consequently the flame does not touch its bottom, there are placed four smaller leaden pans and scratch-pans, which, for a salt-pan of fifteen feet, are usually about a foot and a half long and a foot broad, and three inches deep. These have a bow or circular handle of iron, by which they may be drawn out with a hook when the liquor in the pan is boiling.

The salt-pan being filled with sea-water, a strong fire of pit-coal is lighted in the furnace, and then, for a pan which contains about fourteen hundred gallons, the salt-boiler takes the whites of three or four eggs, and incorporates them all with two or three gallons of sea-water, which he pours into the salt-pan, while the water contained in it is only lukewarm, and mixes this with the rest by stirring it about with a rake. In many places they use, instead of eggs, the blood of sheep or oxen to clarify the sea-water, and in Scotland they do not give themselves the trouble of clarifying it at all. As the water heats, and approaches boiling, there arises a black frothy scum upon it, which is collected into four small pans at each corner of the boiler, called "scratch-pans;" and a great part is also taken off with flat wooden skimmers. This impurity is earthy matter proceeding from the decomposition of certain earthy salts, and is called by the workmen "scratch." After this the water appears perfectly clear, and by boiling it briskly about four hours, a pan loaded in the common way, that is about fifteen inches deep, will begin to form crystals upon its surface. The pan is then filled up a second time with fresh sea-water, applying the eggs or bullock's blood, and the operation of skimming as before: about the time when it is half filled, the scratch-pans are taken out and emptied of a white powder, seeming a kind of calcareous earth, which separates itself from the sea-water during its boiling, before the salt begins to shoot. When these have been emptied they are again put into their places, where they are afterwards filled again. This powder, being violently agitated by the boiling liquor, does not subside till it comes to the corners of the pan, where the motion of the mass is smaller, and it there falls into these

pans placed on purpose to receive it. The second filling of the pan is boiled down after clarifying in the same manner as the first, and so a third, and a fourth; but in the evaporation of the fourth, when the crystals begin to form themselves, they slacken the fire, and only keep the liquor simmering; in this heat they keep it all the while that the salt is granulating, which is ten or twelve hours. The granules or crystals all fall to the bottom of the pan; and when the water is almost all evaporated, and the salt lies nearly dry at the bottom, they rake it all, altogether, into a long heap on one side of the pan, or into two heaps, one at each end of the pan, where it lies a-while to drain from the brine, and then is put into barrows and carried to the store-house, and delivered into the custody of his majesty's officers. In this manner the whole process is usually performed in twenty-four hours, the salt being commonly drawn out every morning. This is the method in most of our salt-works, but in some they fill the pan seven times before they boil up the salt, and so take it out but once in two days, or five times in a fortnight. In the common way of four boilings, a pan of the usual size, containing one thousand three hundred gallons, they draw from fifteen to twenty bushels of salt every day, each bushel weighing fifty-six pounds.

When the salt is carried into the store-house, it is put into *drabs*, which are partitions, like stalls for horses, lined at three sides, and the bottom with boards, and having a sliding-board on the fore-side to draw up on occasion. The bottoms are made shelving, being highest at the back, and gradually inclining forward; by this means the brine remaining among the salt, easily separates and runs from it, and the salt in three or four days becomes sufficiently dry. In some places they use cribs and barrows, which are long and come wicker baskets for this purpose, and in some places wooden troughs with holes in the bottom. The saline liquor which remains from the making of salt, is what is called *bittern*.

The sides of the pans in which the salt is made, are soon crufted over with the same sort of matter, formed into cakes or crufts, that falls in powder into the scratch-pans; this the workmen call "stone scratch;" thus distinguishing it from that skimmed from the top, which they call "powder scratch;" they are obliged to cleanse the pans of it once in a week or ten days, otherwise they will be burnt. In England they do this with iron picks, but at Halle in Saxony they have a much better method; for they there take out the pans, and turning them bottom upwards, burn straw under them, by which means the matter of the cruft loosens itself, and after this it falls off on being struck with a mallet or hammer.

In Lancashire, and some other parts of England, sea-salt is made in this manner; they pare off, in dry weather, in summer, the surface of the flats, which are covered at full sea, and bare when the tide is out. When they have procured heaps of this they put it into troughs, and pour fresh water on it; this washes off the salt that hung about the sand, and is received to impregnate into vessels set underneath the troughs. So long as this liquor is strong enough to bear an egg, they put on more water; when an egg sinks in it they throw the sand out of the troughs, and put in fresh from the heaps. The water thus impregnated with salt they boil in leaden pans, and evaporate to a dryness, the salt remaining behind.

Brine or fountain salt is prepared from the water of salt wells and springs. See *SALT-Brine Springs*.

The ancient methods of boiling brine into salt, in Cheshire and Worcestershire, are accurately described in the Transactions of the Royal Society; and the method, formerly

used in Staffordshire, is delivered in Dr. Plott's history of that county; but the method now generally used in England is this.

The brine being received from the well into a large cistern, is thence received, as occasion requires, into the salt-pan. These pans are of the same form with those used in the boiling of sea-salt, and usually hold about eight hundred gallons; in some places these are made of iron, and in others of lead. When the brine is put into the pan, a little blood is mixed with it, in order to clarify it, and leaden pans are placed at the corners to receive the scratch, or calcareous earth, that separates from them in the boiling. An ounce of blood is sufficient for eight hundred gallons of brine. In some places they clarify their brine with whites of eggs. As soon as it is boiled, it is carefully skimmed, and afterwards it is suffered to boil very briskly for some time, till the salt is granulated; after this the scratch is separated, and the fire slackened, till the whole salt is formed.

When they have separated the scratch, and the salt is ready to crystallize, they put into the pan several sorts of seasoning, as they call them, such as ale, butter, and the like, which they suppose correct the bad qualities of the brine, and make the salt of a smaller grain. After this they boil it very gently, and when as much salt is formed as will fill two or three of their wicker baskets, they rake it up to the sides of the pan, and fill it into the baskets, placing them over the leach trough, that the brine may drain into it from the salt. The salt taken out they call a "draught" of salt, and the operation, a "clearing" of the pan.

In this manner they draw the salt, and clear the pan five or six times during each process, leaving at last only a few quarts of brine at the bottom of the pan. The baskets into which they put the salt out of the pan are called also *barrows*; they usually contain about a bushel of salt, and are of a conic figure, open at the base. The whole process of working a pan of brine usually lasts about twenty-four hours. After the salt has drained an hour or two in the baskets, it is removed into the hot-house over the furnace, where it remains four or five hours to be thoroughly dried, and is then taken out of the baskets, and laid up for sale. In all the English salt-works, the leach brine, which is what remains in the pan after the salt is crystallized, and what drains from the salt in the baskets, is not thrown away, as it is in Germany, but is added to the pan next to be boiled. And beside the salt made in this manner, they have, at most of the English salt-works, a different kind, which they call *silver salt*. This is of a larger and firmer grain than that prepared in the common way, and is stronger, being formed by a milder heat, and therefore more fit for preserving meat. When they would make this salt, they fill the pans on Saturday night, and then, as they draw out no salt on Sundays, there is a very moderate fire kept up all that day, and on Monday morning all the salt is taken out at one draught, having had time to form itself into larger crystals than ordinary, as it is eight and forty hours instead of four and twenty in forming.

They have also another kind of salt, made up in form of sugar-loaves, in small wicker baskets, which is thence called *loaf-salt*, or *basket-salt*. This is the whitest, driest, and finest grained of any salt, and is therefore greatly esteemed at table. In preparing this salt they use some resin and other additions, to break the grain and render it very small; others also, to this purpose, boil it the more briskly, and stir it briskly all the while. But in Cheshire, where the best basket-salt is made, they use no particular process about it, but only take the second and third draughts of every pan, which always are the purest salt; and they do not suffer

these to lie so long in the pan, as when they make salt of a larger grain, but take it out before it can form large crystals; by this means they have it of a fine small grain, and they then press it hard down into the wicker baskets, and when dried in the stove, they let it remain in the baskets for sale.

Not long since, Mr. Lowndes published a method of greatly improving the English brine-salt, so as to make it at least equal to the French bay-salt.

The method is this. Let a brine-pan, containing about eight hundred gallons of liquor, be filled with brine to within an inch to the top; then make and light the fire, and, when the brine is just luke-warm, put in either an ounce of blood from the butchers, or the whites of two eggs. Let the pan boil with all possible violence, and as the scum rises take it off. When the fresh or watery part is pretty well decreased, throw into the pan the third part of a pint of new ale, or the same quantity of the grounds of any malt liquor. When the brine begins to grain, add to it the quantity of a small nut of fresh butter, and when the liquor has stood half an hour longer, draw out the salt. By this time the fire will be greatly abated, and so will the heat of the liquor; let no more fuel be thrown on the fire, but let the brine gently cool, till a person can just bear to put his hand into it; keep it in that degree of heat as nearly as possible, and when it has worked for some time, and is beginning to grain, throw in the quantity of a small nutmeg of fresh butter, and about two minutes after that scatter throughout the pan, as equally as may be, an ounce and three quarters of common alum, pulverized very fine; then instantly, with the common iron scrape-pan, stir the brine very briskly in every part of the pan for about a minute; then let the pan settle, and constantly feed the fire, so that the brine may never be quite scalding hot, yet always a great deal more than luke-warm; let the pan stand working thus for about three days and nights, and then draw it, or take out the salt. The brine remaining will, by this time, be so cold, that it will not work at all, therefore fresh coals must be thrown upon the fire, and the brine must boil for about half an hour, but not near so violently as before the first drawing; then, with the usual instrument, take out such salt as is beginning to fall, and put it apart; then let the pan settle and cool. When the brine becomes no hotter than one can just put one's hand into it, proceed as before, and let the quantity of alum not exceed an ounce and a quarter, and about eight and forty hours after draw the pan, and take out all the salt. Lowndes's Brine Salt improved.

This is Mr. Lowndes's process; except that he afterwards directs cinders to be chiefly used in preparing the fires, the better to preserve an equal heat, and by that means also he proposes saving a considerable expence, asserting that at present cinders are so little valued in Cheshire, as to be thrown out into the highways. Mr. Lowndes adds, that in a pan of the size before-mentioned, there may be prepared, at each process, sixteen hundred pounds weight of salt from the best brine in Cheshire, and one thousand and sixty-six pounds from the ordinary brine of that country. This, as the process continues five days, is a little more than five bushels and a half of salt a day from the best brine, and a little more than four bushels a day from the ordinary kind.

The salt-boilers, and particularly those that prepare brine-salt, have long been accustomed to make use of various substances, which they call additions or seasonings, and mix them with the brine while it is boiling; either when they first observe the salt begin to form, or else afterwards during the time of granulation. The intention of these additions is to make the salt grain better, or more quickly form into

crystals, to make it of a small fine grain, to make it of a large firm and hard grain, and less apt to imbibe the moisture of the air, to render it more pure, and to make it stronger and fitter for preserving provisions.

The additions commonly used for these purposes are wheat-flour and resin, in order to give the salt a small grain; butter and tallow, to make the brine crystallize more readily; new ale, stale beer, bottoms or lees of ale and beer, wine lees, and alum. Wine lees, new ale, stale ale, and the lees of ale and beer, are now generally rejected by the marine salt-boilers; except in the west of England, where the briners, who use them, affirm that they raise a large grain, and make their salt more hard and firm, and some say that they make it crystallize more readily.

Hoffman prefers the strongest ale; and Plot assures us that it makes the salt of a larger or smaller grain according to the degree of its staleness. Dr. Brownrigg apprehends that the only good effects which fermented liquors can have, as an addition, are owing to their acid spirit, which may correct the alkaline salts of the brine, and thus render the common salt more dry and hard, and less apt to dissolve in moist air. For correcting the alkaline quality of the brine, if any additions are thought necessary, he recommends stale ale or Rhenish wine; or perhaps malt vinegar would answer the same purpose. Alum and butter were long used in Cheshire, but the use of the former has been discontinued. Mr. Lowndes introduced it, with a view of correcting the slackness and softness of brine-salt; but Dr. Brownrigg is of opinion, that alum cannot answer these purposes, and that it is not necessary; for, he says, that the grains of common salt will always be sufficiently hard, and of their natural figure, large size, and undeliquable, if formed by a gentle heat and perfectly free from heterogeneous mixtures; and he imagines, that the goodness of Mr. Lowndes's salt is not owing to the alum, but to the gentle heat used in the preparation of it. The addition recommended by the Dutch will appear in the sequel of this article.

We may observe that bay-salt and boiled salt have respective different qualities, according as they are prepared at different places; and there are two general causes of this diversity; one respects the manner of preparing the salt, the other respects the quality of the water from which the salt is prepared. When sea-water or brine is boiled into salt, a portion of the acid, which is one of its constituent parts, is dispersed; and a greater or less portion is dispersed, according as the salt has been formed with a greater or less degree of heat. We have an instance of this, both in bay-salt compared with boiled salt, and in the different sorts of the latter, when compared with each other.

Bay-salt, which is prepared from sea-water, by the mild heat of the sun, is generally esteemed much stronger than the white salt, which is prepared likewise from sea-water, by boiling the water. Hence this salt is not only weaker, but more disposed to deliquesce in the air; both which imperfections are said to be corrected by a small addition of fresh acid, when the salt begins to congregate. Hence also distilled sea-water is manifestly impregnated with acid, so as to be unfit for drinking, or for the common purposes of life; unless a little chalk, vegetable ashes, or other like substances, be added in the distillation, to absorb and keep down the acid extricated by heat; by which means the distilled fluid proves perfectly sweet.

White salt is prepared by boiling either the natural brine of sea-water, or salt-ponds and springs, whence are obtained the marine salt and brine salt, or the stronger brine produced by artificial means, viz. by previous evaporation, or solution of fossil salt, or the impregnation of common salt drawn

from earths, sands, or stones. Of this salt two very different kinds are required; the one for the use of the table, and the other as a condiment for provisions. Its whiteness, dryness, and the smallness of its grains, are the properties which chiefly recommend the first kind, and its strength and purity the latter.

Dr. Brownrigg has proposed a method of improving the preparation of both kinds, founded on the following principles; *viz.* 1. That in the common processes for making white salt, the salt is deprived of a considerable part of its acid spirit, by the violent boiling used in its preparation; whence it is rendered less fit for preserving fish, flesh, and other provisions, than it would be if prepared with a more gentle heat. 2. That most kinds of white salt are rendered impure by the mixture of various heterogeneous substances, which render it less proper for preserving provisions than it would be if separated from them.

In order to obtain a salt of this kind, free from all impurities, and in no respect weakened by a dissipation of its acid spirit, let the sea-water (if that be used) be heightened into a strong brine by the sun, after the method practised in Hampshire, and other parts of England, or in a salt-marsh constructed after the French manner.

For this purpose, a salt-pan must be erected adjoining to the salt-marsh, and a large boiler, or salt-pan, made of iron, placed in it. The bottom of the pan may be of a square figure, forty feet on each side, and its depth may be eighteen inches; or it may be made of a cylindrical form, forty feet in diameter, and eighteen inches deep, like those used in Holland. The furnace over which the pan is erected may have four mouths, made on the opposite sides at equal distances, for the convenience of receiving fuel. The fire may be made on a hearth; and within the furnace must be erected proper pillars of brick, or mid-feathers; and, if necessary, strong posts and cross bars of iron, to support the bottom of the salt-pan. There must be also four funnels, for conveying away the smoke, at equal distances, between the mouths of the furnace. If the pan be square, the funnels may be carried up at its four corners, and the mouths may be under the middle of its four sides. To the mouths must be fitted close doors, and the funnels must be furnished with registers, for regulating the fire. When this apparatus is provided, let the salt-pan be filled with strong brine, drawn from the cistern, and well cleared from its muddy sediment. Then kindle a fire, and mix a sufficient quantity of whites of eggs with the brine, in order to clarify it; let the brine boil gently at first, and let it be well skimmed. When this is done, diminish the fire, and apply a moderate heat, sufficient to keep the brine of a scalding heat.

When the salt begins to grain, rake out the scratch, which will be found at the bottom of the pan. When the brine is thus fully depurated, in order to correct its alkaline quality, a proper quantity of four whey may be added to it; the brine being kept of a scalding heat, while the salt is graining or forming into crystals; and when most of it is crystallized, and lies in the pan almost dry on its surface, the fire must be damped by shutting the doors of the furnace and registers; and the salt must be drawn from the liquor to the sides of the pan, and put into drabs, or proper vessels, till the bitter liquor is drained from it, and then it will be fit to be used in the second process of refining.

In this way may be prepared a sea-salt stronger, and of a much finer and larger grain, than any kind of common white salt made by the ordinary methods; and also a salt for the table, better in quality and cheaper than that prepared by the common methods. However, it is necessary to observe, that the salt which is required of a fair grain,

should be granulated with quicker fires, and drawn out of the pan before it hath lain long enough to form itself into large crystals, so that it may be taken out at five or six draughts during the process. The second or third draughts will be the best salt, being most free from scratch, and the salts of the bitter. After the same manner, a good kind of white salt may be extracted from natural brine, and likewise from a solution of rock-salt in weak brine or sea-water.

In the second process of refining, a sufficient quantity of the white salt, prepared as above directed, should be put into a large cistern, made of wood, or bricks and clay; and to this should be added as much pure river-water as will be sufficient to reduce it to strong brine, almost fully saturated with salt; when the salt is dissolved, and the brine has remained unmoved, a scum will arise which must be taken off, and a sediment will fall to the bottom. Let the clear brine be drawn out of the cistern into a salt-pan, such as has already been described in the first process, well cleansed from bitter; let a fire be kindled in the furnace, and the heat be so gentle, that the watery part of the brine may be slowly evaporated without any of the saline spirit; for this purpose the heat should be regular, and less than the heat of boiling water; but the degree which salt can endure without any dissipation of its acid spirit, is best known by experience, and may be adjusted by the registers, &c. When the evaporation is so far advanced, that little saline crystals begin to appear on the surface of the brine, then may be added to it a sufficient quantity of the acid muriatic spirit (in the proportion of about one, two, or three drops of the spirit to a gallon of the brine), so that neither the acid, nor the alkaline principle of the salt, may be predominant. When this is done, the evaporation must be continued until the surface of the salt in the pan is almost dry. The doors of the furnace and registers must then be closed, and the fire smothered out, and the salt, which will be found in large clear crystals, must be raked to the sides of the pan, and having drained there a little while, be taken out, and put in proper vessels to drain farther from the superfluous brine, and it will be then fit for sale.

The strong brine which remains in the pan after the refined salt is drawn out, and the brine that drains from it, ought not to be mixed with the solution intended to be made into refined salt, but will serve to mix with the brine, to be boiled up in the first process into common white salt. See on the subject of this article Brownrigg's *Art of making Common Salt*, 8vo. 1748, passim.

Foreign salt, which has undeliveredly been held in great estimation in this country, is formed from sea-water, in hot countries where the natural heat is sufficient to evaporate the water from the salt. The sea is let into pits or basins made on purpose, and lined with clay, to prevent the water from sinking into the earth. When one quantity is evaporated more water is let in, till the brine becomes saturated.

The white salt of Normandy is not made by refining the bay-salt, but has this colour naturally when taken out of the pits. To make it they gather a muddy sand on the flats of the shore, which the rising tide has covered and impregnated with its waters for seven or eight days. This sand being removed into pits for the purpose, discharges itself by degrees of all its water, which filtrates through some straw, with which the opening of the pit is filled, and trickles into vessels set on purpose to receive it. Of this water it is that they make their salt.

Their furnaces are of earth, and their boilers of lead: each furnace boils four leads. When the water with which they have filled the leads begins to boil, they take off the

scum, which arises in abundance; and in proportion as it diminishes, throw in fresh water, which they continue to skim, as before. When it thickens, they keep it continually stirring, with a crooked stick or ladle; and when the grain is formed, they take it off the fire to purify it.

The purifying is performed by letting it stand in large osier baskets; where it drains itself of certain humidities that remained. When dry it is laid in heaps, and thence is carried into the magazines.

The commerce of salt has brought an immense profit to France, though more to the king than to the makers and sellers; on account of the heavy duty, which used to be one-fourth part of the price the salt was sold at. The English and Dutch, and (when they are at war with France) the Swedes and Danes, have taken off most of the salt of the Comte Nantois; paying for it, *communibus annis*, from 20 to 35 livres the load. That of Guerande has been preferred, by the English and Irish, to all the rest, as the best. Yet that of Borneuf, though browner, and heavier, is most used in France, as also throughout the Baltic; particularly in Poland, where, besides the ordinary uses, it serves in tilling the ground; being found to warm it, and prevent little vermin from gnawing the grain.

The English and Dutch have often striven hard, in times of war, to do without the French salt; and to that end have endeavoured to take salt from the Spaniards and Portuguese; but there is a disagreeable sharpness and serosity natural to this salt, which renders it very unfit for the salting of flesh, fish, &c. To remove this, they boil it with sea-water, and a little French salt, which they procure by means of neutral nations, which not only softens it, but increases its quantity by one-third. But it should seem their refining does not succeed to their wish, by the eagerness with which they return to the salt of Bretagne, &c. as soon as any treaty has opened the commerce. See *SALT-Markets*.

In the south of France these works are carried to a great extent. The land generally destined for this purpose is flat, having a clayey soil, and not liable to inundations. It is surrounded by a wall or bank, having inlets next to the sea,

capable of being opened and shut at pleasure. The land thus allotted is divided into fields or compartments, of from fifty to one hundred acres. When the evaporation is so far advanced that the salt begins to be deposited, it is pumped up on a platform elevated above the fields, for the purpose of giving free access of air, by which the remaining water is evaporated. As the water evaporates more brine is pumped up, till the salt is formed into a crust of about three inches in thickness. This platform is divided into many compartments, connected with each other by a common gutter. When the salt has become hard it is broken into pieces, and laid up in heaps, sheltered from the rain. It will be obvious, from what has been observed of the English salt extracted from sea-water, that this incrustated mass must contain a certain portion of those earthy salts which constitute the *bittern*. This bitter fluid drains from the incrustated heaps for a long time, and the salt made in this way is not deemed perfectly good till it has been exposed for three years. In some places these drainings are collected for the purpose of procuring sulphate of magnesia, and other preparations containing magnesia. When salt is not freed from these deliquescent salts, it is apt to become moist in the air, and has a disagreeable bitter taste.

This salt is called *bay-salt*, and a prejudice has prevailed in its favour in most countries, as possessing more valuable properties in preserving animal food. The valuable essay by Dr. Henry, to which we have before referred, deserves the greatest praise, inasmuch as it clearly proves that the foreign salt, so far from being superior to the Cheshire salt, is very inferior to it in those points on which its preserving quality depends. This prejudice has made us dependent upon France, Spain, and Portugal, for an article which we might with as good reason export.

The following table is the result of Dr. Henry's analysis, which was conducted with great skill, and with his usual accuracy. It may be observed here, that it is the opinion of several chemists, that salt, and the bittern in which it is formed, contain sulphate of soda. From Dr. Henry's experiments this appears to be a mistake.

One Hundred Parts by Weight consist of

Kinds of Salts.		Insoluble Matter.	Muriate of Lime.	Muriate of Magnesia.	Total earthy Murates.	Sulphate of Lime.	Sulphate of Magnesia.	Total Sulphates.	Total Impurities.	Pure Muriate of Soda.
English Sea-Salt	Ignat									
	St. Ubes	9	a trace	3	3	23½	4½	28		960
	St. Martin's	12	ditto	3½	3½	19	6	25		959½
	Oleron	10	ditto			19½	4½	23½		964½
	Scotch (common)	4		28 &c. +	28 &c. +	15	17½	32½		935½
	Scotch (Sunday)	1		11½	11½	12	4½	16½		971
	Lymington (common)	2		11 &c. +	11 &c. +	15	35	50		937
	Ditto (cat)	1		5	5	5	5	6		988
	Crushed rock	10	0½	0½	0½	6½		6½		983
	Fishery	1		0½	1	11		11½		986
	Common	1		0½	1	14½		14½		983
	Stoved	1		0½	1	15		15½		982

The three first specimens are of the foreign or bay-salt. In the column marked total quantity of impurities, it will be seen that they are not by any means so pure as the four last, which are the Cheshire salts. A large portion of their impurities, it will be seen by the second column, is insoluble

matter, which is principally clay, derived from the platform on which it was evaporated, which is formed of wood, and plaistered with clay to make it water-tight. The sulphate of lime is doubtless an ingredient of the sea-water. Perhaps the circumstance of the heaps of salt being left so long to

drain out their deliquescent salts, may account for their containing so small a quantity of the muriates of lime and magnesia, and sulphate of magnesia.

Dr. Henry gives another reason for the deficiency of the latter substances in bay-salt. The evaporation being very slow, the crystals are much larger than those produced by artificial heat alone, which is the case with the British specimens obtained from sea-water: and since the deliquescent salts can exist only upon the surface of the crystals, it will be evident that the quantity contained in any salt, will be as the surface exposed, which will be as the number of crystals in a given mass, and inversely as their size.

This very clearly shews why the bay-salt is less contaminated with the deliquescent salts. The reason why bay-salt contains more sulphate of lime than the British, will be explained from the pains taken to remove the matter which is separated while evaporating. The sulphate of lime, being sparingly soluble, is separated in clearing the pan; and forms also a part of the incrustation at the bottom of the pan, called *scratch* in the salt-works in the North, and *pan-scule* in Cheshire. The Scotch common salt, for reasons above given, contains a large proportion of the deliquescent salts, and of sulphate of magnesia. The evaporation is carried on rapidly; in consequence of which the crystals are small, which gives a greater surface for the moist salt to adhere to.

The Sunday salt is so called, from the fire being let out from Saturday night till Monday morning. The evaporation, by this means, is slower, and the crystals larger, and in consequence presents a less surface for the retention of the liquid impurities.

The Lymington common salt contains nearly the same quantity of impurities with the Scotch common. But the quantity of sulphate of magnesia much exceeds the muriates. The quantity of impurities in the two varieties depends upon the similarity of their crystals, with respect to surface, the quality of each depending upon the sea-water from which it is obtained.

The cat-salt, of the formation of which we have before spoken, is formed by a very slow crystallization; hence its crystals are large and smooth on the surface; and hence, as will be seen in the table, it is the most pure of all the varieties.

In the four last, which are the Cheshire salts, it will be seen that the impurities differ much from those obtained from sea-water.

The crushed rock-salt, exclusive of its insoluble matter, would be nearly pure. This impurity is, doubtless, similar to that separated in cleaning the pan, viz carbonate of lime and oxyd of iron. The remainder is sulphate of lime, a substance generally existing plentifully in the same stratum which contains the rock-salt. The other specimens have little insoluble matter, the impurity consisting chiefly of sulphate of lime, which becomes precipitated with the crystals of the salt as the evaporation goes on. Dr. Henry, with his usual sagacity, conjectured that the sulphate of lime would be the most abundant in the salt which first falls to the bottom, and the least in the last portions. Thus he found to be the fact.

			Sulphate of Lime.
The common salt, drawn out two hours	$\left\{ \begin{array}{l} \text{contained} \\ \text{in 1000} \\ \text{parts} \end{array} \right\}$	-	16
after the heat was applied		-	11
Salt drawn four hours after		-	3½
Salt drawn six hours after		-	

He also properly observes, at the same time, that the impurities derived from the soluble salts will be the least in the first salt which falls down, and the greatest in the last.

Inasmuch as the smallness of the crystals is favourable to the concealment of the soluble impurities, it is also the cause of this salt not being so well fitted for salting provisions which require merely to be stratified with the salt. The fluids which proceed from the animal matter tend to dissolve the salt, and the solution will go on more slowly as the crystals are larger; because the surface is less. By this means the salt is more completely insinuated, and in consequence more effective. From this reasoning Dr. Henry concludes, that salt in large grains or crystals is best fitted for the stratifying mode of salting, and small salt better adapted for making brine or pickle, in which the substance is immersed.

This view of the subject may suggest some reason why a preference has been given to the foreign bay-salt. For, although it is not so pure as the Cheshire common salt; yet, from the slow way in which it is evaporated, the crystals are larger, and in consequence possess the advantage above stated. The large-grained fishery-salt, however, is certainly superior to the bay-salt for the stratifying method of salting. Indeed, its name seems to have arisen out of its own celebrity; and it is no uncommon practice for this salt to be sold as bay-salt. In all salt-works these hints may be turned to some account, particularly in the manufacture of fishery-salt. By a more protracted evaporation, the crystals will be larger, which has two advantages in that made from sea-water:—the salt will contain less of the soluble impurities, which are the muriates of lime and magnesia, and sulphate of magnesia; and it will be as well fitted for all purposes as the foreign salt, the importation of which is a national evil, and a disgrace to those who prefer it to our own large-grained salt.

SALT upon Salt, a kind of common salt prepared by the Dutch, of great use in preserving herrings and other fish, and to which they principally owe their advantages in the herring-trade. The Dutch prepare two kinds of refined salt, one of a small grain, intended for the use of the table, and called butter salt. They export large quantities of this to the countries upon the Rhine, and into other parts of Germany. The other kind is a very strong and pure salt, and is of the largest grain of any boiled salt now made: this salt they call the St. Ubes's or Lisbon salt, from its resemblance to the pure bay-salt made in those places.

The salt which they refine is altogether marine bay-salt, and they chiefly have it from France and Spain; but they find, by experience, that any one kind of bay-salt does not answer their purposes so well as two or more kinds; they therefore frequently mix three parts of Cadiz salt with one part of that of Soultion, which is of great strength, but very dirty, and of a green colour, and does not cost above half the price of the Spanish salt: for dissolving the bay-salt they use sea-water, which they bring in lighters to Dort and Rotterdam from below the Brill or Helvoet; out of these lighters it is craned into cellars, and is thus impregnated with bay-salt to a certain degree of strength, which they determine by hydrometers made for that purpose. After the heavy dross of the salt is subsided at the bottom of the cellar, the clear brine is pumped up into the salt-pan through a mat, which retains the light scum, straws, or other impurities, which floated on the surface of it. These salt-pans are of iron, of a round figure, and commonly forty feet in diameter, and eighteen inches deep. These pans are placed over a hearth-furnace, and the only fuel they use in boiling the salt is dry turf. The fire is kept up so high, that the liquor boils briskly all the time, and if any scum arises, they carefully take it off, but

they use no clarifying mixtures. A little before the salt begins to granulate, they add to the pan a lump of butter, of the bigness of a walnut, and half a pint of four whey, which has stood at least half a year. This acid whey, called *azy*, unites itself with the uncombined fixed alkali contained in the salt, and thus prevents it from adhering to the common salt as it crystallizes. Any other mild acid might probably answer the same purpose. When these things are perfectly mixed in by a good stirring, they shut the doors and windows of the house, that no air may blow in cold, and the house is kept thus hot all the time that the salt is forming. This method is not new or peculiar to the Dutch works, for Agricola describes an apparatus of boards to keep the cold air out of the salt-pan all the time that the salt is forming; and the Germans use it, in many places, at this time.

It is out of this same brine, and by the same process, that they make the table-salt and the strong salt; only towards the end of the process they make this difference; if the pan is to be wrought into table-salt, the brine is kept gently simmering during the whole operation, and all is finished in twenty-four hours; but if it be to be made into a strong salt, they slacken the fire to such a degree, that the operation takes up three days. In both cases they let the salt remain in the pan till the whole is finished; they then rake it out with wooden rakes, and after it has drained a-while in wooden drabs, it is fit for use. The mother-brine, of which there always remains a large quantity in the pan after the strong salt is made, as also the drainings of the drabs where the salt is put, is reserved to be boiled up into table-salt; but the mother-brine of table-salt becomes more sharp and bitter after every process, and is finally thrown away.

The principal uses to which salt is applied, are as a seasoning in our food, in the making of butter and cheese, the curing of hams, bacon, and fish, and the preservation of animal and other substances. For the first of these purposes it seems almost an indispensable necessity, so insipid would be most kinds of food without it. It is remarked, with some truth, that its flavour is agreeable to most other animals as well as man. There are places in America where the sea occasionally overflows, which, on the water evaporating, leaves the salt. These places are called *licks*, and are the resort of vast crowds of different quadrupeds, whose object is to lick the ground for the sake of the salt. It is said that hay, sprinkled with salt, is eaten by cattle with greater avidity. Salt has been said to be injurious to health when taken in more than common quantity. It would, however, be difficult to mark out any inconvenience in those who take more than is generally taken. Each person acquires the habit of a certain dose in his food, above or below which he would feel great inconvenience in taking it. Some countries far removed from the sea, and having no supply from the mineral salt, are obliged to extract it from the ashes of certain vegetables. In some places it is so valued from its scarcity, as to become a substitute for coin. In some of the northern countries, where fuel is scarce, the sea-water is let into ditches lined with clay, and the water, on freezing, concentrates the salt in the remaining fluid, which, being saturated, requires less evaporation. The use of salt in preserving food is found to have some disadvantages. Although it preserves the food, it ultimately changes its nature, and destroys its nutritious qualities. We have striking instances of these effects in the sea-scurvy, which is not produced by the salt in the meat, but from its being deprived of its nutritive qualities and rendered indigestible. Pickles or vats made with fugar, nitre, and a little salt, are said to preserve meat better, without injuring its quality.

Sir Humphrey Davy supposes that the power of salt in preserving animal and vegetable substances is owing to its attraction for water, by which the decomposing action of that fluid is prevented, as well as to its power of excluding air. And Dr. Holland, who seems to have attended much to the subject, thinks, that although the different sorts of this substance differ little in their nature or purity in consequence of the manner in which they are made, it may readily be conceived, that their difference in form, as well as compactness, may fit them for very various applications in these intentions, especially in the preservation of animal flesh and provisions. But in every case, the more pure the salt is, and the more free from any admixture of foreign alkaline or earthy saline matter, the more effectual it will be for the purpose it is designed. Thus it is supposed by the writer just mentioned, that for table use, the salting of butter, and various domestic purposes, a preference should be given to the finer kind of salt, or that which is prepared by a boiling heat; as the smallness of its grain fits it in a better manner for all such applications. It is also better for the making and preserving of cheese; and in that process, as well as in the making and preserving of butter, it is particularly proper, in consequence of its blending, incorporating, and uniting itself in so equal and intimate a manner with the different substances. It may likewise be the most proper for preserving different kinds of vegetable substances on the same account.

For the like reason of the smallness of its grain or particles, as well as from its consequent readiness of solution, the same sort of salt may, it is said, be well, or perhaps the best adapted of any for making the pickle for *striking* the meat, which, with the rubbing it well on and into the substance, for which such a state of its parts admirably fits it, is the primary proceeding in the preserving of animal flesh, and the first part of the process in the curing of fish in the fisheries, or in other ways and intentions.

But it is contended, that for the purpose of *packing* fish and provisions of the meat kind, it is by no means so proper, or so well fitted and efficacious, as the common or large-grained fishery-salt; for, as might be expected, it is found, when applied to this purpose, not to preserve them in an equally effectual manner from taking on or running into the state of putrefaction. This, however, is stated to arise, not from any want of purity in the salt, or from any admixture of earthy salts or other matters with it; but from the smallness of its grain or particles, and its want of hardness and compactness, originating from the circumstance of its containing a larger proportion of the water of crystallization than the larger grained salt. Therefore, in consequence of its being so ready of solution, the whole of it is formed into brine; which, it is thought, by being forced out from betwixt the layers of flesh or fish, by the pressure of these on each other, the different portions of animal matter are allowed to come into close contact, without having any salt interposed. Whereas, on the contrary, when the salt of a larger grain is employed, a considerable part of it continues long undissolved; separating the different layers or portions of meat; admitting in some degree the brine to flow and insinuate itself betwixt them; and furnishing a constant new supply of saturated brine, from the gradual solution of the salt in the fluids exuding from the animal matter, to every part of the packed provisions or other matters.

And it is further suggested, that the action or operation of bay-salt in the same intention, is exactly similar to that of the large-grained salt; and that neither the one nor the other would seem to have any superiority or advantage

over the fine salt prepared by a boiling heat, except in so far as the size and compactness of its crystals are concerned; and in containing a somewhat smaller proportion of the water of crystallization. And that, as the large-grained fishery-salt, which is prepared by a low degree of heat from natural brine, is, it is thought, more than equal to the bay-salt in these important points; there can be no doubt, whatever prejudices to the contrary may have existed, or have been formed on the matter, that it at least equals the latter in its power of preserving animal flesh, or provisions, and perhaps other substances.

As experience, however, has much more weight than any theory or opinion on such a subject as the present, the writer has had recourse to it in support of his reasoning on the matter. This sort of experience is had, it is said, on an extensive scale, at the victualling-office near Deptford, at which, it is stated, the large-grained salt manufactured in this country from natural salt-brine springs, has for several years been the only salt used for packing provisions, after they have been first salted or cured with common salt, or that which is prepared by a heat of one hundred and eighty degrees. And it is asserted, that though these provisions have been afterwards carried to the hottest climates, the strength and purity of the salt employed in preserving them have never been called in question. They have kept perfectly well, and it has never been doubted that the salt used there, was in every respect equal to the St. Ubes' salt; or to any other salt prepared from sea-water, by the natural heat of the sun. It is remarked, that what is sold in the metropolis as bay-salt, is almost wholly the large-grained salt of home manufacture from natural brine-springs or others of the same quality.

However, strongly rooted prejudices in favour of bay-salt in the preservation of meat and fish still exist in Ireland, Scotland, and perhaps in some parts of this country, which cannot be removed, except by some change in the duties of the foreign or imported salt, and that which is made in this country, by which the latter may be sold at a much lower rate than the former. And such a regulation would seem desirable, as large sums are now annually paid for bay-salt, which might be saved to the country without any disadvantage.

The state and form of salt, as the consequence of the method of preparing it, are therefore constantly to be considered in the rural and other practices of curing meat and other substances. See SALT-Brine Springs.

It has been suggested by the first of the above writers, that where animal or vegetable food is to be preserved on a large scale, he is disposed to believe that it may be in some measure effected by forcibly throwing a quantity of carbonic acid, hydrogen, or azote, into the vessel, by means of a compressing pump, similar to that contrived for making artificial Seltzer water. In this way any change in the substances would, it is thought, be more effectually prevented. And no elastic fluid would, in such cases, have room to form by the decomposition of such matters; besides, the tightness and strength of the vessel would be proved by the process. That as no putrefaction or fermentation can go on without the production of elastic fluid; pressure would probably act with as much effect as cold in preserving these sorts of provisions.

With regard to alimentary salt in general, we may observe, that though it appears to us under various forms, it is immediately distinguished by applying it to the tongue, and its always assuming the same figures after a regular crystallization. Its crystals are cubes, several of which unite together into the form of hollow truncated pyramids.

Common salt dissolves in water, and cold water dissolves nearly the same quantity as hot boiling water, nor does it concrete again in the cold, like the other neutral salts, as long as the evaporation of the fluid is prevented; but writers are not agreed about the proportion of salt dissolved in water. Some say, that it dissolves in less than thrice its weight of boiling water; others say, that it requires $3\frac{1}{2}$ times its own quantity of water; and others again say, that four parts of water to one of salt are required for a perfect solution. These differences may be easily accounted for by the different salts that may have been used. Boerhaave is of opinion, that 16 ounces of water will not dissolve quite five ounces of rock-salt; Spielmann, with whom Neumann agrees, thinks that they will dissolve 6½ ounces; Eller says, that seven ounces of fossil salt may be dissolved in 16 ounces of water; and Hoffmann assures us, that 16 ounces of water will not dissolve above six ounces of common salt. Dr. Watson's experiments confirm that of Hoffmann; for he observes, that he never could dissolve quite six ounces of rock-salt in 16 ounces of water. The sea-water in different parts of the world is very differently saturated with salt; that of some parts containing twice as much as others. The sea-water which surrounds the coasts of Great Britain, is said to hold seldom more than one-thirtieth, or less than one-fiftieth part of common salt. When water is impregnated with any salt, as much as it can bear, it will still dissolve a quantity of another salt, whose particles are of different figures, proper to insinuate into the remaining vacuities of the water: thus, after common salt will no longer dissolve in it, alum will; and after alum, saltpetre; then sal ammoniac, &c.

Although common salt is very crystallizable, and exactly neutral, it very readily becomes moist when exposed to humid air, and must, therefore, be kept in dry places. This salt contracts an union with common salt with a calcareous basis, and, consequently, all the salt obtained either from sea-water, or salt fountains, contains a certain quantity of this salt with earthy bases, the white earth of which will precipitate by adding fixed alkali to a solution of common salt in pure water. In order to obtain a very pure common salt, it is necessary to dissolve it in water, filtrate it, and add a solution of crystals of soda, or marine alkali, till no more white cloud is formed by the addition; then filtrate the liquor again, and evaporate it.

The crystals of common salt, exposed to the fire, crackle and burst, and thus form the *sal decrepitatum*, soon after melt, and when cool, fix in form of a white and almost opaque mass. This salt is absolutely unalterable by fire, even when it has been heated strongly together with inflammable matters; a property which results from the slight disposition which its acid has to combine with phlogiston, as the experiments of Messrs. Duhamel and Margraaf have demonstrated. However, though it be fixed in the fire to a certain degree, yet when it is exposed to a violent fire with free access of air, it exhales in vapours, and attaches itself in white flowers to bodies less hot than itself. Chemists know no other acid but vitriolic and nitrous acids, and sedative salt, which can decompose common salt by disengaging its acid.

Common salt is of all saline substances the most necessary and useful. Its acid and alkali are employed in many chemical operations in the arts; it is an important ingredient in the fusion of glass (see GLASS), which it whitens and purifies; it facilitates the fusion and precipitation of the metallic parts of minerals in assays, and perfectly covers them; and its peculiar use in preserving meats, &c. seasoned with it, or steeped in solutions of it, and in improving the

taste of aliments, is universally known, and has been already mentioned. In the application of salt to this important purpose, it retards and prevents the putrefaction of almost all our aliments, without producing any such change upon them, even when preserved a long time, as to render them altogether unfit for nourishment. And though salted animal foods are generally accounted one of the principal causes of the scurvy at sea, this is owing not to the salt itself being prejudicial, but to its being incapable of preserving the animal subjects, for a length of time, in a perfectly uncorrupted state. Pure sea-salt, and sea-water, are rather salubrious than hurtful, both in the true *scurvy*, (which see,) and in impurities of the blood and humours in general.

Hoffmann observes, that an ounce of the salt, dissolved in a proper quantity of water, occasions commonly six stools or more, without uneasiness; that this salt checks the operation of emetics, and carries them off by stool; that in glysters it is more effectual, though used only in the quantity of a drachm, than any of the purgatives; and that where other glysters fail of opening the belly, a solution of common salt produces effect.

With regard to the antileptic property of common salt, it is proved by the experiments of sir John Pringle, Dr. Macbride, and M. Gardane, in his Essay towards a History of Putrefaction, that, though when mixed with animal substances in a large proportion, it preserves them from putrefaction, yet when a small quantity of it is employed, it considerably accelerates putrefaction. Whence it appears, that small quantities of common salt, such as are taken with food, facilitate digestion, which is a kind of incipient putrefaction, and serve at the same time as a mild stimulus to the stomach itself: and, therefore, common salt is not only agreeable and useful, but also salutary, at least to all constitutions in which the digestion is too remote from putrefaction, as in those which are properly called crudities; though different temperaments may differ much in this respect. Common salt is observed to differ from other saline substances, in occasioning drought, and tending, not to cool, but rather to heat the body. Lewis's Mat. Med. and Macquer's Dict. Chem. Eng. ed. art. *Common SALT*.

SALT, Common, Laws relating to. By 38 Geo. III. c. 89. the management of the salt duties is transferred to the commissioners of excise; and by 43 Geo. III. c. 69. 45 Geo. III. c. 14. and 47 Geo. III. sess. 2. c. 30. several duties are imposed upon it; and by the last act the additional duties charged by that and the preceding are charged upon Glauber and Epsom salts. And 65 pounds weight avoirdupois of rock-salt shall be deemed a bushel, and 56 pounds of every other kind of salt. (38 Geo. III. c. 39. f. 4. 45 Geo. III. c. 14. f. 4.) The act 47 Geo. III. sess. 2. c. 30. recites the provisions previously made for imposing duties on salt as follows: By 43 Geo. III. c. 69. a duty of 10s. is imposed for every bushel of salt and rock-salt made at any salt-work or taken out of any mine in England, and a duty of 4s. for every bushel of the same in Scotland; and by 45 Geo. III. c. 14. an additional duty of 5s. for every bushel (as above) in England for home consumption, and 2s. in the same manner in Scotland. By the former act an allowance is directed to be made of 10s. for every bushel of salt of English manufacture, used by any bleacher of linen or cotton in England, in the making of oxygenated muriatic acid for this purpose, and so in proportion for any greater or less quantity, deducting at the rate of $7\frac{1}{2}$ per cent. in consequence of the increase in the weight of the salt by the moisture of the air, and an allowance of 4s. for every bushel of salt used for the same purpose in Scotland, with a similar deduction: and by the

47 Geo. III. sess. 2. c. 30. a farther allowance on salt used by bleachers in making oxygenated muriatic acid, out of the duties imposed by 45 Geo. III. c. 14. of 5s. for every bushel of salt of English manufacture, consumed in England, and with the deduction above stated, and 2s. on every bushel consumed in Scotland for the same purpose, and subject to the same deduction.

The act 43 Geo. III. c. 69. imposes a duty of 13s. 4d. for every bushel of salt imported into Great Britain, not being Irish salt imported directly from Ireland; for every ton of rock-salt, which shall be exported to parts beyond the seas, other than Ireland, 1d.; for every bushel of salt or rock-salt brought from Scotland into England, with a certificate that the duty of 4s. has been paid, 6s.; and for every bushel of salt employed in curing and salting fish, exported from Scotland to England, 6s.; and for every cwt. of salted beef or pork, or bacon, brought by land from Scotland to England, 2s. 6d. The said act allows drawbacks of 10s. for every bushel of salt made in England, rock-salt excepted, for which all the duties have been paid, and duly exported; of 4s. for every bushel of salt made in Scotland, similarly circumstanced; and of 10s. for every bushel of Glauber or Epsom salts. By 45 Geo. III. c. 14. an additional duty of 6s. 8d. is imposed on every bushel of salt imported into Great Britain (not being Irish salt imported directly from Ireland); for every bushel of Irish salt or Irish rock-salt, or Irish Glauber or Epsom salt, imported into Great Britain, an additional duty of 5s.; and by the same act the following drawbacks are allowed, viz. for every bushel of English salt (rock-salt excepted) duly exported, 5s.; and for every bushel of Glauber or Epsom salt, made in Great Britain, duly exported, for which the duties have been paid, 5s.; and for every bushel of salt made in Scotland (rock-salt excepted) in the same circumstances, 2s.

But the duty imposed by this act shall not extend to any foreign or British salt delivered or received for the sole purpose of curing or preserving fish. By 47 Geo. III. sess. 2. c. 30. 6d. of the duty of 2s. 6d. per cwt. (under 43 Geo. III. c. 69.) on salted beef or pork, or bacon, brought by land from Scotland to England, shall cease.

Commissioners may compound for the duty with the refiners of rock-salt, and also for the duty on mineral alkali or flux for glass. (45 Geo. III. c. 14. f. 7.) The importer of foreign salt shall pay the duty upon entry, and before landing, under the penalty of forfeiture of the said salt, and all vessels, horses, carriages, &c. employed in removing, landing, or conveying the same, which may be seized by any officer of excise or customs; and every person employed, or to whose house the salt shall come after having been unshipped, knowing the same, shall forfeit treble its value: s. 8. If any salt be imported without entry and payment of the duty, within 20 days, such salt shall be forfeited, and may be seized: s. 9. Provided nevertheless, that such foreign salt, not less than 50 bushels, upon entry and before payment of the duty, may be landed in preference of an officer, weighed and warehoused upon bond being given in double the amount of the duty, to pay and clear off the duty when sold, if within 12 months, and if not sold within that time, then at the end of such 12 months: s. 10. The warehouses are to be secured under the joint locks of the officer and proprietor; nor shall any salt be put into or taken out of such warehouse in less quantity than 50 bushels, at one time, and after proper notice of 12 hours, and with the attendance of an officer: s. 11. No foreign salt shall be imported in any vessel of less burden than 40 tons, except for the use of the seamen, not exceeding 5lbs. for each man, upon pain of forfeiting such salt and

vessel, &c. f. 13. No salt shall be imported from Ireland, Guernsey, Jersey, Sark, Alderney or Man, except for the use of seamen, not exceeding 2lbs. for each man, and is liable to forfeiture with the vessels, and may be seized; but fishing vessels, having a due quantity of salt, received from entered warehouses, or other vessels employed in fishing, are exempted: f. 14. By 45 Geo. III. c. 14. f. 19. no salt shall be imported from Ireland into Great Britain in any ship of less burden than 100 tons, under penalty of the forfeiture of salt, vessel, &c.: and by f. 10 and 11, if any person shall put on board any vessel in Ireland more than in the proportion of 2lbs. of salt for each person employed in the ship, without notice and bond, he shall forfeit all such salt, and 100*l*. By f. 14. no rock-salt shall be refined, or made into white salt, at any place in Great Britain beyond the distance of ten miles from the salt-mine or salt-pit from which the rock-salt has been taken; except at such works as have been duly entered for the purpose one year previous to the passing of this act: and places for making salt in England are to be entered, on pain of forfeiting 100*l*., the salt, and articles used in making the same, &c. f. 17. By 38 Geo. III. c. 89. officers may enter and take an account at any time by day or night. Proprietors are to provide warehouses and store their rock-salt in them, &c. under penalty of 100*l*. f. 19. Proprietors are to give notice of their intention to take salt out of the mine, under forfeiture for every offence of 20*l*. No rock-salt shall be taken out of such warehouse, but in the presence of an officer, no less than four bushels at a time, and between the hours of five in the morning and seven in the evening from March 24th to the 29th of September; and between seven in the morning and five in the evening from 28th September to 28th March, in each year, under penalty of forfeiture of salt, &c. and 40*l*. for every bushel of such salt, or 50*l*. at the election of the attorney-general, or person who shall sue: f. 21. Makers and refiners of salt shall provide suitable warehouses, with proper fastenings, which shall be kept locked, except when the officer attends, under forfeiture of 50*l*. f. 22. Such maker shall give six hours' notice in writing before he begins to charge any pan or boiler, which notice shall specify whether he intends to make larger grained, commonly called fishery-salt, or fine-grained salt, under penalty of 20*l*. for each offence: f. 23. And he shall proceed without delay, on pain of 20*l*. Brine may be added once and no more: f. 24. But the whole operation must be finished before fresh brine is put in, under penalty of 50*l*. f. 25. The salt taken from each pan is to be kept separate, and within ten hours after it has been taken out, the maker shall specify in writing to the proper officer the quantity made at such boiling; and when the officer has taken account of it, all such salt shall be removed into the maker's entered warehouse, on pain of 20*l*. Half the salt of one boiling may be warehoused before the whole is finished, nor is any salt to be warehoused till an account is taken, under forfeiture of 20*l*. for every pound, or 100*l*. at the option of the attorney-general, or the person suing: f. 30. Salt may be removed to warehouses at Liverpool or Bristol for the purpose of exportation; and bond shall be given, which bond shall be discharged, upon leaving with the proper officer, within three months, a certificate that such salt was duly delivered and secured at such warehouse: f. 33. 70, 71. The salt removed to export warehouses may be immediately shipped, without being warehoused, and the bond be discharged: f. 72. Salt shall not be removed out of warehouses, except at stipulated times, under penalty of forfeiting the same, carriages, horses, &c. and 100*l*. for every such offence: f. 34. Salt shall not be removed without a permit, under the penalty of forfeiting as before, and

40*l*. for every pound, or 100*l*. at the pleasure of the attorney-general, or person who shall sue: f. 35. Persons removing salt without a permit shall on conviction forfeit 50*l*. or be committed to the house of correction for any time not exceeding 12 months: f. 36. Warehouses are to be approved by the officer, and repaired or altered according to his directions; and if such warehouses be opened or entered by any person but in the presence of the officer, he shall for every offence forfeit 20*l*. f. 37, 38. And if any lock or fastening provided by the officer at the expense of the proprietor be removed or broken, the delinquent shall forfeit for every such offence 100*l*. f. 39. And it shall be repaired by the proprietor within a reasonable time, on pain of forfeiting 20*l*. f. 40. Notice is to be given when it is proposed to take salt out of the warehouses, and the officer is to attend. The proprietor shall be discharged from payment of duty for rock-salt taken out for refining, for exportation, or for curing of fish: f. 41. Rock-salt may be made into white salt at the appointed place, and no other, under forfeiture of 200*l*. f. 15 and 16. (45 Geo. III. c. 14. f. 14.) Permits shall be granted upon application by a note in writing: f. 43. The permit shall be returned after the time limited on demand, on pain of forfeiting 50*l*. for every offence; and giving false permits incurs a penalty of 500*l*. for every such offence: f. 104. f. 132. Duties shall be cleared off within a week after entry, or bond be given in double value: f. 45, 46. Removing rock-salt without a permit incurs a forfeiture of the same, and carriages, cattle, &c. and persons concerned in so doing incur a penalty of 500*l*. f. 48. Scales and weights are to be provided by the proprietor, and his servants are required to assist, on forfeiture of 100*l*. f. 50, 51. He that conceals salt to evade the duty forfeits the salt and 50*l*. f. 52. Officers may seize salt found in vessels and carriages suspected of being clandestinely removed, and persons offending shall forfeit the salt and carriages, &c. and 40*l*. for every pound weight: f. 54. The proof of payment of duty lies on the owner, and not on the officer who seized the same: f. 56. Previous notice is to be given of shipping salt for exportation, and bond shall be given in treble the value for payment of the duty, for the due exportation, and that it shall not be reloaded in Great Britain. Salt for curing fish may be imported, and must be duly entered: f. 12. Before such salt is delivered duty free, bond in double the amount of the duty shall be given that such salt shall be delivered to the fish curer, &c. The rates at which salt for curing fish shall be allowed are as follow:

For every hundred weight of cod, ling, or hake, 50 pounds of salt.

For every barrel containing 32 gallons of wet cod, ling, or hake, 56 pounds of salt.

For ditto 42 gallons of salmon, 36 pounds of salt.

For ditto 32 gallons of white herrings, 140 pounds of salt.

For every barrel containing 32 gallons of red herrings, 65 pounds of salt.

For ditto 32 gallons of clean shotten red herrings, 56 pounds of salt.

For every last consisting of 1000 dried red sprats, 25 pounds of salt.

For every cask containing 50 gallons of pilchards or scads, 336 pounds of salt. 42 Geo. III. c. 93. f. 20.

For 32 gallons of mackarel, 84 pounds of salt.

And so in proportion for any greater or less quantity.

No salt shall be used in curing pilchards or scads more than twice; and in taking account of salt only once so used, credit shall be given to every fish curer for such salt, as containing of pure salt in the proportion of three parts in four

of the whole quantity and no more; and every officer of excise shall make his computation according to such proportion. 42 Geo. III. c. 93. s. 21.

And every barrel, cask, or vessel, in which fish, beef, or pork, entitled to any bounty shall be packed, shall be gauged according to the gallon English wine measure. 38 Geo. III. c. 89. s. 5.

All salt imported from Scotland without a legal permit testifying that all the duties payable in Scotland have been paid shall be forfeited, together with the packages, ships, boats, and other vessels, waggons, carts, and other carriages, horses and cattle employed in removing the same, which may be seized by any such officer; and the person in whose custody such salt shall be found, or employed in removing the same, shall forfeit 50*l.* s. 86.

No salt shall be removed from Scotland to England by land, on pain of forfeiting the same, together with the packages, waggons, carts, carriages, horses and cattle employed in removing thereof, which may be seized by any such officer; and every person concerned in removing the same, contrary to the directions of this act, shall forfeit 40*l.* for every pound weight thereof, or 100*l.* at the election of the attorney-general, or person who shall sue. s. 87.

By 49 Geo. III. c. 81. salted beef, pork, or bacon, brought by land from Scotland to England, shall immediately on the arrival thereof in England, be entered at the nearest excise-office in England; on pain of forfeiting the same.

Every maker of glass may take rock-salt from any warehouse belonging to any salt-mine, or brine or sea-water for making mineral alkali, or flux for glass, upon bond being given that the same shall be so employed; such bond to be discharged upon oath being made before the collector that all such rock-salt, brine, or sea-water, for which the same was given, was made use of in making such mineral alkali or flux for glass, and for no other purpose whatsoever. s. 116.

Every person before he begins to make mineral alkali or flux for glass, shall make entry in writing of every work-house, warehouse, storehouse, room, or other place, and also of every utensil or vessel by him intended to be used therein, at the excise-office of the district. And if any such person shall begin to make any mineral alkali or flux for glass, without making such entry, he shall forfeit 100*l.* together with the same, and all materials proper for making the same, together with the utensils and vessels used therein, found in any unentered place. s. 117.

No such rock-salt shall be delivered out of such entered warehouse, for the purpose of making mineral alkali or flux for glass, or shall be afterwards delivered at such alkali works, or be deposited in any warehouse or place belonging thereto, but in the presence of an officer, who shall make an entry in writing, containing the weight or quantity thereof, and the day when so delivered, and the name of the maker of glass to whom delivered, and for the use of what works. s. 119.

In case the rock-salt so brought to be stored in any such alkali works, shall be less in weight or quantity than specified in the permit, the maker for whose use the same was delivered shall be answerable for the same. s. 120.

If any such maker, on whose account such rock-salt shall have been delivered as aforesaid, or if any other person shall use the same or any part thereof, or any acid materials to be produced therefrom, after being used in making such mineral alkali or flux for glass as aforesaid for any other purpose, he shall forfeit 100*l.* s. 121.

Any officer of excise may enter any such work-house or

place made use of by any such manufacturer of mineral alkali or flux for glass, and if such manufacturer shall upon demand in the day time (and if in the night, in the presence of a constable or other peace officer) refuse to permit such officer to enter, he shall forfeit 50*l.* s. 122.

Provided always, that nothing herein shall extend to impose any duty on such Glauber salts as shall be made by any glass-maker in any of the processes of making mineral alkali or flux for glass, and which shall be *bonâ fide* expended and consumed in making such mineral alkali or flux for glass: s. 123. See however 47 Geo. III. sess. 2. c. 30. s. 2.

And whereas salt is an essential ingredient in making oxygenated muriatic acid used for bleaching linen and cotton, and allowing a drawback on salt used for that purpose would promote the manufacture thereof, it is enacted that the whole duties now payable on salt of British manufacture shall be drawn back for all salt consumed in making any such oxygenated muriatic acid as aforesaid. Provided, that no such drawback shall be granted for more or other salt than shall be mixed with vitriolic acid, manganese, and water, in the presence of an officer, and in the proportion of at least 20 pounds of vitriolic acid, 20 pounds of manganese, and 10 pounds of water to every 56 pounds of salt. Nor shall any such drawback be granted to any person not being a bleacher of linen or cotton, nor unless he make entry in writing of every work-house or place intended to be used in making such oxygenated muriatic acid as aforesaid at the next excise-office. Provided also, that any officer of excise may at all times, by day or night, upon request enter into any such work-house or other place used by such bleacher, and by weighing, gauging, or otherwise, take an account of all salt therein, and of the state of operation of such oxygenated muriatic acid. s. 89.

By 47 Geo. III. sess. 2. c. 30. s. 1. divers allowances are further made on salt used by bleachers in making such acid.

In all cases where it shall be necessary to ascertain the value of salt, the same shall be taken at the highest price at which the same shall sell for in London. s. 129.

If any person shall counterfeit or forge, or cause to be done, any certificate or debenture, with intent to defraud his majesty, he shall be guilty of felony, and be transported for seven years. s. 131.

If any person shall obstruct any officer in the due execution of his office, or shall by force rescue, or attempt to rescue, any salt, vessel, boat, horse, cattle, cart, or carriage, he shall for every such offence, for which no penalty is particularly provided by this act, forfeit 200*l.* s. 133.

If any person shall offer or give any bribe to any such officer, in order to corrupt him in the execution of his office, or to connive at or conceal any fraud relating to the duties on salt, whether such proposal be accepted or not, he shall forfeit 500*l.* s. 134.

And all fines, penalties, and forfeitures hereby imposed relating to the duties on salt, may be sued for, recovered, levied, and mitigated as by the laws of excise, or in the courts of Westminster, and shall be applied half to the king (except where otherwise expressed), and the other half to him who shall sue. s. 136.

Provided, that nothing in this act contained shall extend to repeal or alter any act in force relating to the duties on salt, immediately before the passing of this act, except so far as the same is revoked or altered or repugnant thereto, but all the provisions, regulations, penalties, and forfeitures thereby imposed (except as aforesaid) shall remain in full force. s. 140.

And all powers of 12 Car. II. c. 24. shall extend to this act. s. 142.

And the lord mayor and aldermen of London, and the justices of the peace, at their respective general sessions, may set, ascertain, and publish the price of salt to be sold or exposed to sale (and not intended for exportation) within their respective counties, cities, and places, and may alter the same as they may see occasion; and the prices so set or altered are to be observed by every person selling or exposing salt for sale. And if any person shall sell any salt (except for exportation) at any higher price, or refuse to sell it at the price so fixed as aforesaid, he shall forfeit 20*s.* to be levied by distress, by warrant of one justice; and in default of sufficient distress, such justice may imprison such offender until he shall pay the same, to be applied half to the king, and half to him who shall sue. s. 143. Burn's Justice, art. *Excise*.

There is a custom duty in the city of London, called "grange," payable to the lord mayor, &c. for salt brought to the port of London, being the twentieth part.

SALT, as manure, and for the use of animals, in Agriculture, is a substance which has been said to be found useful, when applied in this way to land, and as food or condiment in the support or fattening of domestic animals. In the former of these applications, there has been much difference of opinion in respect to its effects; some contending that it is highly beneficial; while others think that it is of little, if any, advantage. There are likewise others who have supposed it to be useful, when laid on land in small proportions, while in large ones it has an injurious effect; having, in the former case, a tendency to promote putrefaction; while, in the latter, it may retard it by its antiseptic property, as well as be capable of acting in other ways, in both cases. It has also been supposed to produce much benefit by the power which it possesses of destroying snails, grubs, and other similar animals that may be in the ground. It is observed by Dr. Darwin, that as it is a stimulus which possesses no nourishment, but may excite the vegetable absorbent vessels into greater action than usual, it may, in a certain quantity, increase their growth, by their taking up more nourishment in a given time, and performing their circulations and secretions with greater energy. In a greater quantity, its stimulus may be so great as to act as an immediate poison on vegetables, and destroy the motions of the vessels, by exhausting their irritability. And it has been remarked by the Rev. Mr. Cartwright, in an able paper in the fourth volume of the Communications to the Board of Agriculture, that at present the use of salt, as a manure, is a subject on which the public opinion is much divided: its advocates, reasoning from the striking effects of salt-water on the marshes, which are occasionally irrigated by the sea at spring-tides, conclude that the fertilizing virtue of such irrigation is owing to its saline quality, without taking into consideration the quantity of animal and vegetable matter, which sea-water (particularly near the coast, and where rivers disembogue themselves) must necessarily hold in solution. But that those who maintain a contrary opinion, considering salt merely as an antiseptic, satisfy themselves that it is impossible that any thing can be friendly to vegetation which retards putrefaction, a process indispensable in substances that are to be the food of plants. To get over this difficulty, it has been conjectured, nay, there have not been wanting those (and of great name too) who have even attempted to prove, that salt in small quantities accelerates, as in large quantities it is known to resist, putrefaction; a doctrine to which, however, he shall not willingly yield his assent, till he can be persuaded that effects

are not, in all cases, proportionate to their causes. The operation of every cause is, and must, he contends, be uniform; and when, to appearance, it is not so, some other cause obtrudes itself, too subtle for our observation, which operating at the same time with the primary cause, joins in giving a result, which not being able to account for, we consider as anomalous. He thinks, that theorists should be at variance with each other is not to be wondered at; for having the wide field of imagination and conjecture before them to expatiate in, it is reasonable to conclude, indeed it is unavoidable, that some of them must lose their way. But what shall we say to the disagreement and inconsistency which prevail on the subject amongst practical farmers? Nothing, indeed, can be more contradictory than the different reports that have been made on the effects of salt, as a manure, by those who have even brought it to the test of actual experiment. As there is no reason to question the veracity of the reporters, we must look for the grounds of their disagreement in some predominating circumstance or other, which at the time escaped their observation. Indeed, the success or failure of an agricultural experiment depends so frequently on causes, which can neither be controlled nor foreseen, and so foreign from those which were expected to operate, that it is not to be wondered at if the repetition of the very same experiment gives oftentimes a different result to the inquirer. But as it is not the business of this paper to support a theory, but to detail what has been practised; not to contend for an opinion, but to state facts; the few observations which may be hazarded, will be such only as are required merely in explanation of occurrences, as they arise. He shall endeavour to give, therefore, as simple a relation as possible of the experiments he has tried, to ascertain the advantages or disadvantages which may attend the use of salt as a manure, and also when mixed with the food of animals, and employed in that way.

In regard to the first of these objects, it is stated that the soil on which his trials were made was a ferruginous sand, brought to a due texture and consistence by a liberal covering of pond-mud. Of this soil, in its improved state, he means by the accession of pond-mud, (for having been used merely as a nursery for raising forest-trees previous to these experiments, the nursery-man had not thought it necessary to make use of any other manure), the subsequent analysis is given:

	Grains.
About 400 grains gave of siliceous sand, of different degrees of fineness, about - - - }	280
Of finely divided matter, which appeared in the form of clay - - - - - }	104
Loss in water - - - - - }	16
	400
The 104 grains of finely divided matter contained } of carbonate of lime - - - - - }	18
Of oxyd of iron - - - - - }	
Loss by incineration (most probably from vegetable decomposing matter) - - - }	17
The remainder principally silex and alumine.	

And it is added, that there were no indications of either gypsum or phosphate of lime. And that from this analysis it will appear, he thinks, that these experiments could not, perhaps, have been tried on a soil better adapted to give impartial results; for of its component parts, there is no ingredient (the oxyd of iron possibly excepted) of sufficient activity to augment or restrain the peculiar energies of the substances employed in the business.

It is stated farther, that on the 14th of April 1804, a certain portion of this soil was laid out in beds, one yard wide, and forty long. Of these, twenty-five were manured (the first excepted) in the following manner :

- N^o 1. No manure.
 2. Salt, a quarter of a peck.
 3. Lime, one bushel.
 4. Soot, one peck.
 5. Wood-ashes, two pecks.
 6. Saw-duft, three bushels.
 7. Malt-duft, two pecks.
 8. Peat, three bushels.
 9. Decayed leaves, three bushels.
 10. Fresh dung, three bushels.
 11. Chandlers' graves, nine pounds.
 12. Salt, lime.
 13. Salt, lime, fulphuric acid.
 14. Salt, lime, peat.
 15. Salt, lime, dung.
 16. Salt, lime, gypsum, peat.
 17. Salt, foot.
 18. Salt, wood-ashes.
 19. Salt, saw-duft.
 20. Salt, malt-duft.
 21. Salt, peat.
 22. Salt, peat, bone-duft.
 23. Salt, decayed leaves.
 24. Salt, peat-ashes.
 25. Salt, chandlers' graves.
- N.B. The quantities of each ingredient the same as when used singly.

And that on the same day the whole was planted with potatoes, a single row in each bed; and that the general experiment might be conducted with all possible accuracy, each bed received the same number of sets. That on the 14th of May, (a few days after the plants appeared above ground,) the whole was carefully examined, and the comparative excellence of each row (as far, at least, as could be judged of by appearances) was as carefully registered. The best row was decidedly N^o 7, malt-duft; after which they followed in order, as below.

- N^o 11. Chandlers' graves.
 16. Salt, lime, gypsum, peat.
 25. Salt, graves.
 20. Salt, malt-duft.
 9. Decayed leaves.
 4. Soot.
 2. Salt.
 1. No manure.
 5. Wood-ashes.
 8. Peat.
 13. Salt, lime, fulphuric acid.
 14. Salt, lime, peat.
 17. Salt, foot.
 18. Salt, wood-ashes.
 21. Salt, peat.
 22. Salt, peat, bone-duft.
 23. Salt, decayed leaves.
 3. Lime.
 6. Saw-duft.
 10. Fresh dung.
 12. Salt, lime.
 15. Salt, lime, dung.
 24. Salt, peat-ashes.
 19. Salt, saw-duft.

Further, that on the 28th of May, fourteen days afterwards, the apparent vigour of the plants was in the following order :

- N^o 7. Malt-duft.
 11. Chandlers' graves.
 4. Soot.
 8. Peat.
 16. Salt, lime, gypsum, peat.
 17. Salt, foot.
 20. Salt, malt-duft.
 21. Salt, peat.
 23. Salt, decayed leaves.
 25. Salt, graves.
 1. No manure.
 2. Salt.
 5. Wood-ashes.
 9. Decayed leaves.
 13. Salt, lime, fulphuric acid.
 14. Salt, lime, peat.
 18. Salt, wood-ashes.
 24. Salt, peat-ashes.
 10. Fresh dung.
 3. Lime.
 22. Salt, peat, bone-duft.
 19. Salt, saw-duft.
 15. Salt, lime, dung.
 12. Salt, lime.
 6. Saw-duft.

And that on the 21st of September, the potatoes were taken up, when the produce of each row was in succession, as follows :

N ^o 17.	Salt and foot	-	-	produced	240
11.	Chandlers' graves	-	-	-	220
18.	Salt, wood-ashes	-	-	-	217
16.	Salt, gypsum, peat, lime	-	-	-	201
15.	Salt, lime, dung	-	-	-	199
2.	Salt	-	-	-	198
25.	Salt, graves	-	-	-	195
4.	Soot	-	-	-	192
10.	Fresh dung	-	-	-	192
20.	Salt, malt-duft	-	-	-	189
5.	Wood-ashes	-	-	-	187
23.	Salt, decayed leaves	-	-	-	187
24.	Salt, peat-ashes	-	-	-	185
7.	Malt-duft	-	-	-	184
14.	Salt, lime, peat	-	-	-	183
19.	Salt, saw-duft	-	-	-	180
22.	Salt, peat, bone-duft	-	-	-	178
9.	Decayed leaves	-	-	-	175
13.	Salt, lime, fulphuric acid	-	-	-	175
21.	Salt, peat	-	-	-	171
12.	Salt, lime	-	-	-	167
8.	Peat	-	-	-	159
1.	No manure	-	-	-	157
6.	Saw-duft	-	-	-	155
3.	Lime	-	-	-	150

It is here stated as singular, that of ten different manures, most of which are of known and acknowledged efficacy, salt, a manure hitherto of ambiguous character, is superior to them all, one only excepted! and that when used in combination with other substances, it is only unsuccessfully applied in union with that one, namely, chandlers' graves, no other manure seemingly being injured by it. Possibly its deteriorating effects on chandlers' graves may be owing to its antiseptic property, which resists the putrefactive process, by which animal substances undergo the changes necessary to qualify them to become the food of plants. This, however, he cannot, from any appearance in the soil, when the plants were taken up, assert to have been the case. And the extraordinary effects of salt, when combined with

foot, are, he observes, strikingly singular. There is no reason to suppose these effects were produced by any known chemical agency of foot or salt on each other. Were he to guess at the producing cause, he should conjecture it to be that property of saline substances, by which they attract moisture from the atmosphere: for he observed those beds, where salt had been used, were visibly and palpably moister than the rest, even for weeks after the salt had been applied; and this appearance continued till rain fell, when, of course, the distinction ceased. This property of attracting moisture had greater influence, possibly, on the foot than on any of the other manures; as foot, from its acrid and dry nature, may, he thinks, be supposed to require a greater proportion of water to dilute it than those substances which contain water already. It may be proper to observe, that on those beds where salt had been used, the plants were obviously of a paler green than on the rest, though not less luxuriant; a circumstance which he thought worth noticing, and which he considered, though erroneously, (as appeared by the event,) to indicate a want of vigour, which would be felt in the crop. It was observable also, that where salt was applied, whether by itself or in combination, the roots were free from that scabbiness which oftentimes infects potatoes, and from which none of the other beds (and there were in the field nearly forty more than what made part of these experiments) were altogether exempt. This circumstance deserves the notice of the practical farmer. And it is further noticed by the same writer, that two sets of experiments, and with the same proportions of manures, were tried with turnips and buck-wheat, on a soil the poorest he could meet with, which produced only a dwarf heath and lichen, and which he had pared off. The poverty of this soil will appear by the following analysis:

	Grains.
400 grains gave of siliceous sand - - - - -	320
Of finely divided matter, which appeared as brown } mould - - - - -	68
Loss in water - - - - -	12
	400

And that the finely divided matter lost by incineration nearly half its weight, which shews it contained a great deal of vegetable matter. The residuum, principally a mixture of aluminous and siliceous earths, coloured red by oxyd of iron, and containing very little calcareous matter. There were no indications of either gypsum or phosphate of lime in it.

On July 6, 1804, the pieces set apart for each set of experiments were respectively sown with turnips and buck-wheat. On the 26th, Nos. 1, 2, 4, 5, 6, 7, 19, 20, 21, 22, 24, 25, shewed little or no marks of vegetation. Those that remained were merely in the seed leaf. And that on the 16th of August, four only were alive and in rough leaf, namely,

No. 12. Salt and lime.

13. Salt, lime, and sulphuric acid.

14. Salt, lime, peat.

16. Salt, lime, gypsum, peat.

And it is added, that these four maintained a sickly existence till the middle of September, shortly after which they all disappeared. And it is remarked, that the appearances of the turnips and buck-wheat were so nearly uniform, that he has not thought it necessary to notice the trifling variations between them, which could not have been done without entering into a minute detail, equally tedious and un-

interesting to the inquirer. It is, however, suggested, that though no decisive conclusion can be drawn from these two sets of experiments respecting the advantages or disadvantages of salt as a manure, on such a soil as he has described, because other manures of acknowledged efficacy shared the same fate with the salt, yet this inference may, he thinks, be drawn from them, (and that not an unimportant one,) namely, that a due texture and consistence in the soil is as necessary to the existence and health of vegetables as the pabulum they are sustained by; and this appears evidently by the superiority (such as it was) of those plants where the manure contributed, in any degree, to improve that texture and consistence. This is, he contends, fully shewn by an adjoining field, which within these few years was in a great part in a state of uncultivated nature, equally barren as the spot he has been speaking of; it is, however, now brought into cultivation, and into a decent state of fertility, chiefly from its texture having been improved by a thick coating of marley clay.

But these facts and experiments shew the effects of salt in a more favourable light as a manure, than it has been hitherto generally considered in; and the intelligent writer suggests, that if its beneficial properties were more perfectly demonstrated, the attention of the legislature would devise some measure, without prejudice to the revenue, by which it might be employed for the purposes of husbandry.

There are, in a communication from Davies Giddy, esq. president of the Penzance Agricultural Society, inserted in the twenty-seventh volume of the *Annals of Agriculture*, some interesting experiments on the use of sea-salt in the culture of turnips detailed. They are enabled to make use of this substance as a manure, from the extensive pilchard-fishery established on the coast. Salt is frequently imported for curing fish at 9d. or 9½d. the bushel of eighty-four pounds, and what remains after it has been once, or sometimes twice used in preserving the pilchards, is usually sold at about the same price to the neighbouring farms. Though some animal oil is united to the salt, that which has been the least used is universally preferred, and found the most effectual. It is supposed perhaps difficult to determine whether the whole efficacy of the salt in producing plentiful, and as it would seem, certain crops of turnips, can be imputed to its virtues as a manure, or whether part of the effect may not be owing to the destruction of slugs.

The Report is thus stated by the Rev. John Allen, and Mr. Sickler, two members of the society: at Michaelmas 1790, Mr. Sickler entered on an estate so much impoverished by the former tenant, as scarcely to return the feed.

In the spring of 1791, Mr. Sickler prepared two acres for turnips, which had borne seven crops of oats in succession. The last crop did not produce nine bushels on an acre.

In the first week of April the earth from the ditches was carried into the field, and laid in four piles; each received three cart-loads of sea-shell sand, and five bushels of salt. The earth from another ditch, chiefly consisting of the decayed soil, which had been taken off the ground in former tillage, was placed in three more piles, and each of these received also three cart-loads of sand, but no salt, on account of the apparent richness of the earth. Half the field was manured with the four first piles, but the three last not being sufficient for the other half, what remained was sown with salt, at the rate of ten bushels to an acre.

The part of the field where salt had been used, either mixed with earth, or alone, produced about half a crop of turnips, but the crop totally failed where there was no salt,

In the spring following, white oats were sown, and produced a crop of forty-five bushels to an acre.

In 1792, three acres, which in 1791 had borne a crop of wheat, not exceeding twelve bushels on an acre, were ploughed before Christmas, and brought into fine tilth by Midsummer following. On each acre were sown twenty bushels of salt, excepting that two ridges towards the middle of the field were purposely left without any manure; on these two ridges the turnips totally failed, but the remainder of the field produced a plentiful crop.

In 1793, four acres of land, completely worn out by successive tillage, were ploughed before Christmas; three acres were sown with salt, at the rate of twenty-five bushels, and the remaining acre with eighteen bushels, without any other manure: the crop was in general a good one, but visibly best where the greatest quantity of salt had been used. Crops of turnips have been raised with equal success by the use of salt, since that time, and in the severe winter of 1794-5, it was observed that these turnips were much less injured by the frost than others similarly treated, and cultivated in the common way. When salt is used in the quantity of twenty or twenty-five bushels to an acre, the turnips should not be sown till at least three weeks after the salt. Clover sown with barley after turnips raised by the use of salt, has never failed to produce an abundant crop of hay the year following. It is suggested in the Report, that if the observation can be depended on of turnips being less injured by frost when they are manured with salt, than when they are cultivated in the usual manner, it must indicate an extraordinary degree of health and vigour in the plant; but a single

observation is obviously insufficient to establish such a fact. It is also suggested by Mr. Jay, after observing that the nature of the soil, and perhaps the season should be regarded, as that may possibly account for certain proportions of salt succeeding much better in some instances than in others;—that a gentleman in New England, in America, has published some facts, from which it appears that the subject merits attention.

It is noticed, that in June 1786, he salted one bed of his onions, one bed of his carrots, and one bed of his early turnips: laying the salt under the surface, in the centre of the intervals between the rows, at some distance from the roots, that the salt might have time to be dissolved and altered before the fibrous roots should reach it. The carrots of the salted bed evidently grew much larger and better than the rest, but he could not perceive that the salt was at all beneficial to the onions or to the turnips. And further, that according to Mr. Ford's experiments in salting flax ground, salt seems to be highly beneficial to that crop. He spreads the salt at the time of sowing the seed, and thinks that the quantity should be double to that of the seed: from three acres of flax salted he had fifty bushels of seed, and an excellent crop of flax. Mr. Elliot tells us of five bushels of salt being applied to one acre of flax, which is a much larger proportion, and that it had an extraordinary effect: and also of a crop of wheat increased by salt.

But the trials of Mr. Fenna in Cheshire, with this substance as a manure in various modes of application, do not however appear to have been so successful, though they seem to have been made with much care and attention.

On Fallow.—July 1, 1797. Experiments on a fallow for wheat being once ploughed, and that before Christmas last, full of grass and weeds, owing to the continual wet weather.

	A.	R.	P.		lbs.		Bush.	lbs.
3 butts	0	2	4	sown with	85½	of salt, that is,	2	50 per acre
2 ditto adjoining	0	1	26	unfown.				
3 next ditto	-	0	2	35 sown with	89	ditto,	2	11
2 — ditto	-	0	1	35 unfown.				
3 — ditto	-	0	2	5 sown with	130	ditto,	4	20
2 — ditto	-	0	1	13 unfown.				
3 — ditto	-	0	3	74 sown with	193	ditto,	7	25
3 — ditto	-	0	1	7 unfown.				
3 — ditto	-	0	1	34 sown with	175	ditto,	6	42
3 — ditto	-	0	1	17 unfown.				
3 — ditto	-	0	1	13 sown with	195	ditto,	10	25

Observations.—July 12, 1797. Some few of the weeds have perished, but no other evident alteration, compared with those unfown, and none at all upon those sown with small quantities. Ploughed under between the 7th and 14th of July, the weather being rather drying, but still showery.

July 12. Salt sown on the same fallow being twice ploughed, the weather drying.

	A.	R.	P.		lbs.		Bush.	lbs.
1 butt	0	0	22	sown with	76½	of salt, that is,	9	49 per acre
1 ditto	0	0	18	sown with	78½	ditto,	12	21
1 ditto	0	0	33	sown with	109	ditto,	9	34

Additional Observations.—It is stated that some few snails perished by the application the day following. No other perceptible alteration has yet taken place.—August 28; has been harrowed and ploughed a third time. It is suggested, that a man sowing from a seed-hopper, common stride and full hand, twice over the same ground, will sow from ten to twelve bushels per acre.

Oct. 1, 1797. Sowed another butt in the same fallow with salt, immediately before its being sown with wheat, and ploughed in therewith, being after the rate of ten

bushels per acre. No visible advantage has been seen in any of the above, through the winter, or at spring, nor any perceptible advantage as the crop advanced to maturity; neither could the reapers, nor any other viewers, distinguish the least appearance in favour of salt compared with the butts unfalted.

On Pastures.—June 30. Sowed 0 a. 0 r. 17 p. of pasture with 4 lbs. 4 oz. of salt (being rye-grass and clover of the second year's growth, soil pretty good upon marle).

Sowed 0 a. 0 r. 13 p. with salt (2 lbs. 12 oz.) being pas-

ture of several years' growth, full of wild or natural clover; soil deeper and warmer than the former.

July 1. Sowed o. a. o. r. 35 p. with 17½ lbs. of salt, being pasture of the third year's growth; soil open, upon sand productive of fern.

December 1, 1797. Sowed part of a butt with salt, after the rate of 15 bushels per acre.

December 1. Sowed 8 lbs. of salt on part of a rough meadow, having nearly its whole summer's growth of four grafs, which the cattle would not eat, and has been usually burnt off at spring.

Observations.—July 12. No evident alteration compared with the adjoining land. August 28, continues unaltered.

In spring 1798, not forwarder, nor any wise preferable to the adjoining butts of ground which were not salted.

Some thistles and some little of the fern damaged, but not destroyed. The rough or four grafs being in a withered or dead state, though sown with fine salt when dewy, was not affected thereby, neither did the cattle prefer it to the other not salted.

On Mowing.—July 17. Sowed 39½ lbs. of salt upon o. a. o. r. 14 p. a cold peaty meadow (herbage indifferent, intermixed with rushes) immediately after the hay being carried off, the weather dry. N. B. Eight bushels per acre.

Observations.—July 25. The weather broke, and much rain has since followed, but no visible alteration has yet taken place.—August 27. This is not a sufficient quantity to destroy the herbage, nor has any advantage yet appeared. Neither has the spring nor the crop of hay-grafs shewn any thing preferable to the unsalted parts adjoining.

On Hay.—August 13. Scattered 3 lbs. of salt in a ton of new hay at the time of housing, being a little weathered. This hay appeared less mouldy, and on that account was better than the same unsalted, but would not compare with the like hay which had not been weathered, and not salted.

On Weeds and Brambles.—June 30, 1797. Applied 4 oz. of salt to 4 oz. of weed-wifs (in Gerrard's History of Plants called *geniifella tinctoris*, dyer's weed, or bastard broom), tufts, or roots, occupying a space twelve inches in diameter, in equal quantities. The ground being wet with almost continual rains for a month past.

Observations.—July 1. Began to droop.—July 12. Dead.—August 28. Three of them are rotted away, and their place growing over with grafs; the other has its woody substance yet standing, though dead. These sprang up from the old roots this spring, 1798, and have continued in the same flourishing state as they were before the application of salt, July 1797.

July 1, 1797. Applied 7 lbs. of salt to a number of the hard kind of rush-tufts, or bogs in the pasture.

Observations.—The cows found it the next day, and collected as much as they could, together with every blade of grafs growing amongst the rushes. Some few of the rushes were bit off in consequence of their search; the remainder did not die; nor suffer any apparent damage from the application, August 28. It has been found, by subsequent trials, that the cows take this, in the act of licking the grains of salt with their tongues, and that where the grains have been dissolved, the herbage is not preferable, on account of its having been salted.

July 12, 1797. Ten pounds, used upon a poor furze, or gorse bank, chiefly clay soil, being then almost totally overgrown about twelve or sixteen inches high; in quantity about eighty square yards; the weather dry.

Observations.—The cows found this, and stole all that they could get at, together with any decent herbage with which

it was intermixed. Some little of the gorse has perished, but it is far from being destroyed.

August 28. The whole recovered at the return of spring (1798), and so continues.

July 12, 1797. Used several pounds of salt upon a number of weed-wifs, or bastard-broom, tufts, or roots (the four salted the 30th ult. being dead); the weather dry.

Observations.—July 27. They are in part destroyed. The cows found this, and collected as much as they possibly could, without eating the weed, which is very bitter. It is also observed, that these retained their verdure much longer than those salted in wet weather.—August 28, and not yet destroyed, but much hurt. These, like the former, recovered in the spring of 1798, and so continue (July 1798).

July 12, 1797. Used 10 lbs. of salt upon more rush-tufts or roots in the pasture, a greater quantity to each.

Observations.—The cows found it in a short time, and selected every grafs from amongst the rushes, together with as much of the salt as they could. Some of the rushes suffered in the pursuit, being bitten off and thinned.—August 28. The rush-roots are too deep to be destroyed. Grafs, and other herbage near, has suffered. These, in 1798, are not to be distinguished from the others not salted.

August 25, 1797. Used 6 lbs. upon 15 square yards of ground almost totally overgrown with hen-gorse (in Gerrard's History of Plants called *ononis fve resta bovis*, cammock, or rest-harrow), a pernicious woody shrub infesting clay soils, being then in full flower, and beginning to set its seed-pods; the weather showery.—August 28. The leaves and flowers are dying. The branches died soon after; but the roots sent out fresh ones at the return of spring, which still continue. This being upwards of thirty bushels to the acre, destroyed the intermixed grafs, which became brown and lifeless till the approach of winter, when it began to recover, and the whole was covered by the spring; but no better herbage than the adjoining; nor has it any time since been preferable, July 1798. This quantity was not sufficient to leave the ground quite bare. Though the herbage was killed, it never totally disappeared. If a lesser quantity would have done so, it might have been serviceable for destroying the sward previous to the making of a lay fallow. Salt has been used from fifteen to twenty bushels per acre, upon small patches of nettles in deep-soiled pasture, which were fretted awhile; but afterwards recovered, without any visible alteration in their growth.

It is further observed, that it has likewise been tried (1798) in various proportions, and at different times, upon a turnip fallow, without any good effect. It was sown upon a weedy part of the turnips, to the amount of ten bushels per acre; after they were up in three or four rough leaves, these were fretted; but the greatest part of both weeds and turnips recovered with little variation from the other (rather worse if either). How salt would act upon worms, or what is called the fly, is not known, as the crops were not plagued with them this last year; probably it would have a good effect; for salt-water was tried upon worms on a gooseberry-bush, without fretting the tree much, the worms soon after died; but, as this was only one instance, perhaps a change of weather, or some other cause, might occasion their death. This experiment is intended to be repeated both on turnips and on gooseberries in future. And it is added by the writer, that *with cut straw* salt has been tried, mixed and immediately given, put together and left to ferment, and sprinkled with salt and water; in every case it is refused by the cattle.

And that *in manure*, salt mixed with dung, in various proportions, and in different forts, is not discoverable from the same fort, set on without salt.

On the 3d of January, 1798, 67lbs. of salt were mixed in two square yards of tough peaty parings, cut from the sides and bottoms of an open peaty drain, and made in a heap of that size. The remainder of the same parings were made in another heap, and mixed up with a quantity of horse-dung of proportionate value, allowing the salt to be 2s. *per* square yard. Both forts were examined by Sir Robert S. Cotton, the beginning of August last, at which time the admixture with salt remained in a dead tough state, without any rotten or saponaceous particles in it; the blades of grass in the middle of the heap, though dead, had not lost their colour. No weed or any vegetable had grown upon this heap; but the other mixed with dung was covered with weeds, and on opening was found much reduced and pulverized; and after one good turning and mixing, was set upon the ground in good condition, in November last; the other has since been twice turned, and remains in the heap unrotted at this day, March 1799. From hence it may be concluded, that salt acts not as a septic on vegetable substances, but, on the contrary, preserves them in a dead state, and acts as a preventative to putrefaction: this is perhaps more fully proved by the common method of preserving kidney or French beans, when ripe enough for the table, which are kept the year round for culinary purposes in pots, between layers of dry salt. The writer also states, that from the foregoing experiments it may be concluded, that salt may be of service to agriculture in the preparation of fallows, in rainy seasons unfavourable to the plough; but in this case great quantities must be used to have the desired effect; perhaps less than fifty bushels to each acre would be insufficient: this quantity would not destroy vegetation for more than two months, as appears from the first experiment with weed-wiss, where something more than that quantity was used: this quantity might destroy the weeds, but would not reduce it, if in a tough or soddy state, as appears from the last experiment in manures, where the quantity used is equal to 240 bushels *per* acre, allowing it to penetrate the surface of the fallow, in an equal degree, only three inches deep. And that perhaps it would be more beneficially used in small quantities with hay at the time of housing or stacking, which, if weathered or damp, might prevent it in some degree from becoming mouldy, and, if green and in large quantities, might act as a preventative to overheating and firing. But that as an assistant, or stimulus, to the vegetable system, it appears, through all the foregoing experiments, to be quite destitute of every good property, and unworthy of notice as a manure in any kind of process. And that such is the opinion of several of the neighbouring farmers who have viewed the different applications, and who have, without exception, concurred in the report which is here made.

It is, however, advised by Dr. Darwin, that, because salt, when made use of as a manure, has a tendency to induce disease by its excessive stimulant power, it should be employed a little before the time that the plant would acquire that part of its growth which is wanted. But though this may be done in the garden, it cannot be well extended to the field.

Notwithstanding these results, other trials made in the same district, as well as in others, lead to different conclusions. It was found, in one attempt, on four rushy land after draining, by spreading on one part in the autumn refuse salt, at the rate of eight bushels to the acre, and on another part sixteen bushels to the same extent; that in a

short time the vegetation wholly disappeared, not a blade of grass being to be seen during the early part of the succeeding spring, but towards the end of May a most flourishing crop of rich grass appeared on the eight-bushel portion. After the middle of summer, the other portion too produced a crop still stronger; the cattle were remarkably fond of it, and during the whole ensuing winter, and to this time, which is ten or twelve years since, the land has retained, and still exhibits, a superior verdure to the neighbouring closes. In another trial, in a meadow, the after-grass of which was of so coarse and rank a nature as to be refused by the cattle, on salt being laid upon one part of it, they have ever since preferred the grass growing on that part to every other, and eaten up every blade. It has also, it is said, good effects in mixture or compost with other coarse manures, producing strong crops of barley and hay-grass. On some foul salt being laid upon a court pavement to destroy the growth of grassy matters, though in the first summer afterwards not any thing appeared, in that which succeeded it the vegetation was greatly more abundant than before the salt was used. It has equally beneficial effects, it is said, on fallow land: by using it at the time of breaking up the land, its strong saline properties destroy vegetation and all noxious insects; and mixing intimately with the mould before the grain is put in, it strongly supports and insures the best crops.

In other experiments, when employed in compost with earth, in comparison with lime in mixture with the same earth, on such being laid on different parts of the same field, that part which had the lime compost vegetated strongly, but bore no sort of comparison to the health and vigour of growth in the crop of that which had the salt compost. The latter is still capable of being marked out and traced by the stronger growth of grass or it, notwithstanding the time that has since elapsed.

In using it pretty thickly, without being mixed with the earth on a portion of land, the expected benefit was not only not received, but the vegetation was destroyed, and the ground left almost bare, which was attributed to the manner of application, as being unfavourable and improper.

The water of salt-brine springs, where they break out and spread upon the surface, is however stated to have the effect of destroying all vegetation for the space of several yards about them in particular cases: while in the natural application on the marsh-lands, it appears to produce effects somewhat of a contrary kind; as where the salt-water of the sea overflows them, the vegetation is by no means deficient in vigour.

The difference in the effect of salt, applied as a manure, is attempted to be accounted for by the writer of the corrected Cheshire Agricultural Report, by referring it principally to two causes; namely, a variation in the manner and degree of its application, and a difference in the nature of the soils or lands on which the trials with it have been made. The first of these causes must, it is thought, have a great influence on its action upon vegetable matter as that of a stimulus, and consequently that its effects must be greatly varied by the proportion applied. When employed in a large quantity, it may, like every other excessive stimulus, tend to disorganize and destroy the vegetable substances with which it comes into contact. When used in a smaller proportion, or in mixture as a compost, it may be regarded, by the moderate stimulus it gives to the action of the vessels in the plants, as a promoter of vegetation, and, of course, as a valuable manure. The writer is aware that this is not perfectly conformable to the opinion of some, but he thinks it the most consistent with the general

analogy of nature, as well as with particular experiments on the subject. In fallows it would seem that it might be beneficial in large quantity, by the destruction of all useless vegetable and animal matter; which, at the same time, would be so much reduced and spent by the time the seed was put into the ground, as to fit it for producing that degree of stimulus, which is most adapted to healthy vegetation. The differences of the nature of soils must obviously produce great variety in the results of the different trials which are made to ascertain its particular nature.

Sir Humphrey Davy, in his "Agricultural Chemistry," seems, however, to think it probable that common salt acts as a manure, by entering into the compositions of the plants somewhat in the same manner as gypsum, phosphate of lime, and alkalies. See these heads, *SALINE Manure*, and *SULPHATE of Lime*.

And that as it has been stated, from good authority, that salt, in small quantities, promotes the decomposition of animal and vegetable matter; that circumstance may also render it useful in certain soils and kinds of land. Common salt is likewise offensive to insects. In short, that in small quantities, it is sometimes beneficial in the intention of manure, he thinks, is now fully proved; and that it is probable that its efficacy may depend upon many combined causes. The reasonings against the use of it urged by some, on the grounds, that when applied in large proportions it either does no good, or renders the land sterile, are considered as very unfair and improper; as the circumstance that salt in large proportions rendered land barren, was well known long before any records of agricultural science existed, from the site of a city having been stated in the Scriptures to have been sown with salt, that the ground might for ever remain unproductive. And that though Virgil reprobated a salt soil; and Pliny, who advised it for cattle, affirmed, that when dispersed over land it caused it to be barren, these are not by any means reasons against the proper use of it. The refuse salt of the fisheries of Cornwall have been seen above, and long known to be an excellent manure, but they contain, as well as the salt, some oil and exuvie derived from the animals.

Upon the whole, it is thought not unlikely, that the same causes may influence the effects of salt, as those which have a power in modifying the action of sulphate of lime, as already noticed.

Most lands in this country, especially those near the sea, it is supposed, probably contain a sufficient quantity of salt already for all the purposes of vegetation; and that in such cases the supply of it to the soil will not only be useless, but may be prejudicial. It is noticed, that in great storms the spray of the sea has been carried more than fifty miles from the shore; so that from this source salt must often be supplied to the soil. Salt has also been found in all the sand-stone rocks that the above writer has examined, and it must, it is said, exist in the soil, or the mould that is derived and formed from them. It is a constituent, likewise, of almost every kind of animal and vegetable manure, therefore it must prevail very considerably.

Salt has been employed upon fallows, in some cases, with good effects, and the refuse of it would probably be found beneficial in many circumstances of land, if it was allowed to be taken from works of this nature, free of duty, and which would not unfrequently be a material convenience to the proprietors.

Many additional facts, experiments, and observations will, however, probably be necessary, in order fully to ascertain the nature and utility of salt as a manure.

Use of Salt for domestic Animals.—And it is conceived by

Dr. Anderson, that there is no substance yet known which is so much relished by the whole order of graminivorous animals, as common salt. The wild creatures of the desert are so fond of it, that wherever they discover a bank of earth impregnated with a small proportion of salt, they come to it ever after regularly to lick the saline earth, as they would to a pool of water to drink, were there none other near; so that when a hunter in America discovers such a *lick*, as such places are there called, he reckons himself sure of obtaining plenty of game, by lying in wait near it, and shooting them as they approach, until the whole beasts that have discovered it are killed. And it is also admitted by all those who have tried the experiment, that salt, given along with the food of domestic animals, (except fowls, to which salt is a certain poison,) tends very much to promote their health and accelerate their feeding; and although some persons, who have been at a loss to account for the manner in which this stimulant could act as a nutritious substance have affected to disregard this fact, yet no one has been able to bring the slightest show of evidence, to invalidate the strong proofs that have been adduced in support of it, though, unfortunately for this country, few experiments of this kind have been tried in it. In fact, we have no reason to suppose that salt acts in the smallest degree as a nutritious substance, or of itself tends to fatten any animal; but that merely by acting as a condiment, it whets the appetite, and gives the creature to which it is probably administered a strong relish for its proper food, so as to induce it to eat in a given time a greater quantity than it would have done, and thus greatly to augment, as has been above explained, its feeding quality beyond what it otherwise could have had. In this way it is not, perhaps, an extravagant position to say, that by a proper use of common salt, the same quantity of forage might, on many occasions, be made to go twice as far as it could have gone in feeding animals, had the salt been withheld from them. If so, and let those who are inclined to withhold their assent to this position, prove, by a set of experiments fairly conducted, that it is erroneous; till then, the unvarying testimony of the few who have tried it, confirming the position, ought to be relied on. If so, then we have here laid open to our view an easy mode of augmenting the produce of our fields to an amazing extent; for, if the same quantity of forage can be made to go, not twice as far, but one-twentieth part only farther than it now does, it would be the same thing as adding one-twentieth part to the aggregate produce of meat for beasts, throughout the whole kingdom.

It has also been suggested by a writer in the first volume of the *Memoirs of the Royal Academy of Sciences at Paris*, which is inserted in the 24th volume of Young's *Annals*, that vast advantage may be derived from the use of salt, in promoting improvements in land as well as in increasing the number of cattle. The farmer, it is observed, who has more than an ordinary stock of working cattle, reaps a double advantage, the one by having his work done in season, the other by enriching a greater proportion of his land by means of their additional manure. The only difficulty is how to maintain an increased number without increasing the expence; this, he asserts, may be done by the use of salt, and advances the three following propositions.

1. That salt, given with the food of cattle, augments the nourishment of that food.

2. That in proportion to the quantity of salt eaten by cattle, the effects of that augmentation will be perceivable.

3. That no ill consequence will follow from an excess of salt eaten by cattle, even though it should be given them without stint. And these propositions he endeavours to

support by unquestionable facts. In the jurisdiction of Arles, in the county of Provence, there is a district called the *Craw*, extending in length about six leagues, and in breadth about three, the whole surface of which is covered with small rough stones, and not a tree or bush to be seen in the whole district, except here and there upon the borders; yet on this spot, so seemingly sterile, by the free use of salt, more numerous flocks of sheep are bred and reared than upon any other common, of equal extent, throughout the whole kingdom. And what is no less remarkable, the sheep are healthier, hardier, and endure the severity of winter with less loss, though they have fewer sheep-cots for covering them, than those bred and fed on more copious pastures, and besides they have not the advantage of more convenient shelter. Add to this, that the wool of the flocks bred and brought up in the *Craw* is not only the finest in the whole country, but bears the highest price of any in France. From hence he concludes that it is to the unlimited use of salt that these surprising effects are to be ascribed, for it frequently happens that the *Craw* is so burnt up in the summer that the poor animals are forced to turn up the very stones to come at the few blades of grass that grow round them, and yet none perish for want of food; let every excellence therefore, that can reasonably be supposed inherent in the herbage, be allowed to it, yet the quantity of it is so small, that without the abundant use of salt, a fourth part of the sheep kept in the *Craw* could not subsist in it.

But as a still farther demonstration that this astonishing effect is solely to be attributed to salt, we have, says the writer, in Languedoc, on the borders of the Rhone, a spot of the same kind of stony land, in every respect similar to that of the *Craw*, yet for want of the free use of salt, that in Languedoc does not maintain the tenth part of the number of sheep that are brought up in the *Craw*, though in other respects it is no ways inferior, their wines and other fruits produced in the borders of both being in their goodness and other essential qualities, equal.

Having thus proved his first proposition incontrovertibly, he proceeds to prove the second, and to recommend an easy experiment, which it is in every farmer's power to make, and that is, to give one half of his cattle salt, and the other half none. By this simple trial, in less than a month the difference will be discernible; the cattle to which the salt is given will shew it in their looks, in the sleekness of their coats, in their growth, and in their strength and firmness of labour. He adds, that with little more than half their usual food all these effects will be produced.

In order to establish his third proposition, he appeals to the practice about Arles, where the cattle have as much salt as they will eat, and none are so healthy or thrive so fast as those that eat most of it. It is of course supposed that there can be no doubt of the good effects of salt, in the feeding or fattening cattle; but the manner in giving it to the labouring cattle is not clearly explained. It is stated, that in eight days a flock of three hundred ate fifteen pounds of salt, being one pound to every score; and it would seem that the whole quantity was given in one day, as the farmer is cautioned against letting the sheep drink on the day the salt is given, suggesting at the same time how much it sharpens their appetites.

But the experiments of Mr. Cartwright in respect to the effects of salt, when mixed with the food of animals, have not been extended to sheep, as he did not apprehend that a few limited experiments would either throw new light upon a subject which has already been sufficiently discussed, as applied to those animals, or furnish the public with facts of which it is not already in possession. His experiments have,

therefore, been confined to hogs and cows. It is stated that on July 23d, 1804, three hogs of the same litter, about eight months old, were put up to fatten. Their respective weights were as follow:

No. 1.	44 lbs.
2.	47 lbs.
3.	40 lbs.

And that from the 23d of July till the 7th of August, they were fed with barley-meal mixed up with water, during which time they consumed three bushels and a half of barley, and gained in weight as follows:

No. 1.	12 lbs.
2.	10 lbs.
3.	5 lbs.

But that from the 3d of August to the 21st, they had salt mixed with their food, of which they consumed a quarter of a pound *per* day. The food consumed was four bushels, they had gained upon the last weighing as under:

No. 1.	18 lbs.
2.	22 lbs.
3.	14 lbs.

However, that from the 21st of August to the 3d of September, the salt was discontinued, in which time they eat four bushels and a half of barley-meal, and their increase of weight was:

No. 1.	24 lbs.
2.	21 lbs.
3.	21 lbs.

But from the 3d of September to the 17th, they had salt as before, and their consumption of food was the same as during the last fortnight, namely, four bushels and a half of barley-meal. Their gain of weight was,

No. 1.	31 lbs.
2.	19 lbs.
3.	19 lbs.

They were then slaughtered.

And it is remarked that it did not appear that the salt had any operation either in promoting thirst, or stimulating their appetites, the consumption of food being nearly the same whether salted or not; neither does it appear that the salt had any influence on their fattening; perhaps the quantity allowed them was too little, and yet he should think not, as there was enough to make their whole mass of food sufficiently savory to the human taste. But in trying this experiment he did not confine one parcel of hogs to salt, and another to unsalted food. This mode of trying experiments is always uncertain, as there will be frequently habits and tendencies in the individual animals which will vary the results, and prevent their being uniform. The fairest way, and that which is the least liable to error, is to compare each animal with himself, by feeding him at one period with one kind of food, and then for an equal period with another. If this principle, which he has proceeded upon, be right, there is nothing in these experiments to encourage the practice of administering salt to hogs with a view, at least, to increase their tendency to fatten: how far it may contribute to keep them in health, is a different question, and on which years of experience may probably be necessary to decide.

It is also stated that on the 6th of October 1804, his experiments on cows commenced. On that day two Welsh heifers, one of which had calved about five months, the other three, were confined to the house, and fed with hay for the space of one fortnight. The hay they consumed during that time was four hundred weight nineteen pounds, and the milk they produced was thirty-six gallons three quarts. They had then for the next fortnight salt mixed with their hay, the hay being first slightly moistened with

water, and the salt sprinkled over it; in which time they consumed four hundred weight forty-two pounds of hay, and seven pounds of salt. The milk produced was thirty-seven gallons. For the next fortnight, namely, from the sixth to the twentieth of November, the salt was omitted, and their food was four hundred weight and one quarter of hay, and two hundred weight and a half of cabbages. The produce of milk in that space of time was fifty-four gallons three quarts. From the twentieth of November, their food was the same as before, with the addition of half a pound of salt *per* day. The produce of milk was fifty-seven gallons one quart. It is here noticed that it will be recollected that salt seemed to have no tendency to promote thirst, or to increase appetite in the hogs; yet on the cows its effects in one respect was very perceptible, for during the period they had salt they drank three gallons a day each more than at other times. It is therefore supposed that salt may possibly promote digestion, (notwithstanding its antiseptic quality,) by stimulating the salivary glands, and the glands yielding the gastric juice, and by introducing an increased discharge of their respective fluids, so necessary to the solubility of the different substances received into the stomach, before they can be admitted into the lacteals. And it is suggested that though there may be nothing in the foregoing experiments to lead us to suppose that salt has any other tendency to promote a disposition in animals to fatten than as it may contribute to their health, by aiding their digestion; yet it is probable that, when administered to animals yielding milk, it may contribute in some small degree to increase that secretion; and this it may do by promoting thirst, which induces the animal to drink copiously, in consequence of which the secretion of milk, as well as all other secretions of the fluids, may be augmented. Perhaps, also, it may have a stimulating influence on the lacteals themselves. But that after all, admitting these experiments to prove that salt increases, in some small degree, the production of milk, when that increased quantity is balanced against the price of the salt, the dairy-man will find himself no gainer by such means.

Thus, notwithstanding there does not seem any thing in these experiments, either with hogs or cows, to encourage the practice of giving salt to animals, with a view to increase their disposition to fatten; yet it would be temerity to affirm that it is entirely useless. From the avidity with which most, if not all, kinds of graminivorous animals, whether in a state of domestication or otherwise, are known to eat salt, whenever it comes in their way, it is reasonable to conclude that the propensity has not been implanted in them in vain. But from whatever cause its salutary effects may be supposed to proceed, whether (as was hinted at before) from its promoting digestion, and an increased secretion of fluids, or from any other action it may have on the animal economy, it must be left to an experimenter more successful than he has been, to ascertain the matter in a more perfect manner.

But with regard to sheep, it is well known that salt has long been made use of with advantage in preserving the health and condition of the animal; and that the inconvenience of wet, moist, and otherwise unfavourable land for sheep, may in a great measure be obviated, by having recourse to the giving of salt to the animals. It is indeed the common management, in almost every country but this. The proper mode of giving it is in shallow troughs, being allowed as much as they will take, which is in common but very little, though they are extremely fond of it. Under unfavourable seasons, and where the soil, food, and climate, are not well suited to them, the use of this material has

been found of great service. However, in Mr. Fenna's different trials with this material for sheep, whether scattered in different parts of their pasture, or sprinkled upon other portions, the animals do not seem to have been much attracted by it; as they scarce did any thing more than smell to it, and quit the place where it had been deposited. This might, however, arise from their natural timidity, or their want of being accustomed to it; as many animals are shy in taking new sorts of food, till they get a sort of taste for them. This is the case with oil-cake, and some others.

But it has been suggested by baron Schultz, in the first volume of Communications to the Board of Agriculture, that it destroys the *fasciola hepatica*, or fluke-worm, in sheep. And for this purpose some have recommended, according to Dr. Darwin, one ounce of salt to be given every day, dissolved in water; but that it is probable that it might be used with greater advantage, if hay was moistened with the solution, which would thus, at the same time, supply them with better nourishment than generally falls to the lot of those diseased sheep, on the supposition that they would eat it. But as they take it readily in the manner that has been mentioned above, it may answer the intention in that very convenient method very well.

This substance, on the whole, besides its effects in other ways, as seen above, has the property of moderating the heat in hay-stacks, preserving the green colour, and improving the quality of it. See HAY, &c.

In the early ages of the world salt was regarded as a symbol of extreme sterility. And we read of princes, who, in token of their indignation, sowed grounds with salt to render them barren. See Judges, ix. 45. Deut. xxix. 23. Zephani. ii. 9.

Virgil, Georg. lib. ii. reprobates a salt soil as occasioning the degeneration of fruit-trees, and admitting no melioration from ploughing.

Pliny, speaking of fossil salt, affirms, that every place in which it is found is barren, and unfit for vegetation. And Plutarch observes, that the Egyptians believed salt to be the spittle or foam of the giant Typhon, the great enemy of their gods; and hence, he adds, they held it in the greatest abhorrence.

In later times, however, salt has been frequently used as a manure with great success. It has been the custom, ever since the time of Henry III. at least, for the farmers on the Cornish coast to manure their land with sea-sand, in which sea-salt is so copiously mixed, that in many places it is used to be extracted from a ley made of sand. When the sand has been long exposed to the air, it proves less useful and enriching, which some have attributed to its having been deprived of a good part of its salt by the dews and rains. This practice of manuring lands with sea-sand has, within these few years, been introduced with advantage, in other parts of Great Britain. The Cheshire farmers purchase no inconsiderable quantity of refuse salt from the salt-builers: they mix it with dung, and it makes an excellent manure. At Northwich alone, there were sold, a few years ago, near 3000 tons of it in one year, for the use of the farmers in that and other counties.

In Cheshire, and other counties, they make a great use of the water of their salt-springs, as a manure for their lands. They let out the water of these springs for a certain time upon the lands, after there has been rain, and by this means the quantity of salt they contain is so blended with the rain-water, that it is too weak to hurt the corn or grass, and yet strong enough to kill worms and other vermin, and to improve vegetation.

On the other hand, when the soil abounds with rushes and

weeds, it is customary in Cheshire to lay a quantity of rock-salt upon it, as it is found utterly to destroy every vegetable. And Mr. Tull, observing that common sea-salt is destructive to almost all plants, except those which naturally grow in the sea-water, or on the shores, invented a method of determining how far the horizontal roots of plants run, by burying salt at a distance from them.

From the above observation it should seem, that salt, when used in small quantities, is a good manure, and, when in large ones, a real poison to vegetables.

Some of the African and Arabian deserts are thought to be barren by their having too much salt in them; whilst many parts of Barbary are reckoned to be peculiarly fruitful, from their containing a less quantity of it. As salt, in small quantities, is known to accelerate the putrefaction of animal substances, and when in larger, to retard it, and thus is useful in assisting the organs of digestion in men and other carnivorous animals, as we have already observed, salt applied in like manner, as a manure, may be found very beneficial; not from its entering as an aliment into the substance of vegetables, since there are many experiments tending to prove that no kind of salt can of itself become the food of plants; but from its efficacy in reducing weeds, dried herbage, dead roots, &c. into a putrid oily mass; the fructifying virtue of oily composts being now generally acknowledged: but when it is used in a large proportion, by preserving these matters from corruption, and drying up or hardening the fibrous capillaries of the roots, so that they become unfit for sucking in nutriment, the fertility of the ground is diminished, or wholly destroyed. As to the fertility of lands overflowed by sea-water, it may be partly owing to the slime and mud left by it, and partly to the salt contained in it, which, being in a small quantity, may contribute to the putrefaction of the effete vegetable roots, and the consequent production of an oily compost.

There are no lands that fatten cattle sooner than those pasture grounds which are thus, at times, overflowed by salt-water: such, e.g. are the pastures at Erith, near the Thames, which are sometimes overflowed at spring-tides. Some farmers have tried the scattering of salt over their corn-fields, as soon as sown, in the quantity of two bushels to an acre, with good success: and this quantity may be productive of all the advantages which arise from the occasional overflowing of high tides, or natural salt-springs.

SALT is used *symbolically* and *metaphorically*, by sacred and profane writers, in a variety of respects. Accordingly we find it used as the symbol of wisdom, Mark, ix. 50. Col. iv. 1.; and hence we read of Attic salt, denoting wit or mental intelligence. Salt is also used as a symbol of incorruption and perpetuity, Numb. xviii. 19. 2 Chron. xiii. 5. It is also metaphorically used to signify barrenness or sterility, Judg. iv. 15. Zephaniah, ii. 9. Jer. xvii. 6. Salt is likewise the symbol of hospitality, and also of that fidelity which is due from servants, friends, guests, and domestics, to those who maintain them. Thus the governors of the provinces beyond the Euphrates, writing to king Artaxerxes, tell him, "because we have maintenance from the king's palace, &c.;" which in the Chaldee is thus expressed, "because we are salted with the salt of the palace." (See Ezra, iv. 14.) Among the nations of the East Indies it is said to be a common expression, "I eat such an one's salt," for "I am fed or maintained by him."

SALT, in *Chemistry*, &c. See SAL and SALTS.

SALT-Brine Springs, in *Rural Economy*, such springs, openings, or pits, as afford a watery fluid, strongly impregnated with salt or saline matter. The salt obtained from the water of salt-wells and springs, is denominated *brine* or

spring salt. Great quantities of this salt are made in most of the inland countries, as in Germany, Switzerland, Hungary, and in some parts of France and England.

In Somersetshire, Cumberland, Westmoreland, Durham, and Yorkshire, there are many salt-springs, but they are either too weakly impregnated, or situated where fuel is scarce, and for these and other reasons are not worked; but in other parts of England there are many rich and valuable salt-springs, which are worked to great advantage. Of these, some are situated in Staffordshire, a great many in Lancashire, but the chief are those at Droitwich in Worcestershire, and Northwich in Cheshire; about which last place there are many rich mines of fossil salt, above and beneath the beds of which the salt-springs are usually found.

At Namptwich, in the last county, there are also some salt-wells, which have been of very long standing, being supposed by many to have been worked in the time of the Romans. The brine of these springs is found to differ very greatly in its strength and qualities; some yielding much more salt than others, and the salt extracted from some of them being found improper for many uses, for which that of others serves very well.

The brine of Barton and Northwich is almost fully saturated with salt, a pound of it yielding, as some have said, six ounces of salt; but this cannot be strictly true; for, allowing that 16 ounces of water can dissolve six ounces of salt, and no more, it must follow that no brine-spring can yield six ounces of salt from a pint of brine; because 16 ounces of water impregnated with six ounces of salt, constitute a saturated brine, weighing 22 ounces; and, therefore, by the rule of proportion, if 22 ounces of brine contain six ounces of salt, 16 ounces of brine will contain $4\frac{1}{4}$ ounces of salt. Hence we may infer, that the strongest brine-springs will not yield above one quarter of their weight of salt. Accordingly, Dr. Leigh (Hist. of Lancashire, p. 43.) informs us, that some of the strongest springs at Northwich yielded seven or eight ounces of salt from a quart of brine; but a quart of brine weighs considerably more than 32 ounces, the weight of a quart of water: so that the Northwich springs, from this account, do not yield a quarter of their weight.

The brine of Droitwich, Upwich, and Middlewich, contains about one-fourth of salt: some of the springs at Namptwich yield a sixth part of salt; and those of Wetton, in Staffordshire, afford only one-ninth part. In England, we seldom boil weaker brine than the last; but in Germany, and some other places, where salt is scarce, they work springs, whose water is not impregnated more highly than the common sea-water, containing about $\frac{1}{10}$ salt.

Here we may observe, that sea-water, brine-springs, and rock-salt, generally contain, besides common salt, various other earthy and saline ingredients, such as calcareous earth, magnesia, Epson salts, selenites, Glauber's salt, fixed alkali uncombined with any acid, &c. These substances are foreign to the nature of the salt, and injure its quality; and hence it must appear, that common salt may have very different properties, according to the quality of the water from which it is made, or skill of the salt-maker in separating these heterogeneous substances from it.

Although springs of the kind above-mentioned exist in several different parts of our own country, in different degrees of strength, and of different qualities, yet they are perhaps at present no where wrought for the purpose of obtaining salt from them, in any quantity, except in the county of Chester. They are, however, highly interesting and important to that district in several different points of view.

The intelligent author of the corrected account of the agricultural state of that district, says that the principal

brine-springs in it are found in the valleys through which the river Weaver, and the small rivulet the Wheelock, have their course; and, for the most part, near the banks of them. If a weak spring of this nature at Dunham, near the Bollin river, be excepted; and the springs at Dirtwich, in the most southern part of the county; no others, it is said, have ever been worked. By their means, it is supposed, an importance is given to the first mentioned river, that it would not otherwise possess; and that there is probably a greater bulk of carriage on that stream, than on any other river in the island, which is of itself so little considerable. Tracing the course of this river from its source, at the Peck-ferton hills, no springs strongly impregnated with salt are said to be found near it, until the town of Namptwich is approached. But that brine does exist as high up as Brickley, though it has not been ascertained at what depth, or of what strength, seems probable, it is said, from a sinking of the ground, and the consequent filling of the cavity with this sort of fluid, which took place in its vicinity in the year 1657; accounts of which are given by Dr. Jackson, in the *Philosophical Transactions*, and more minutely by Childrey, in his *Britannica Baconica*. Leland has also, it is observed, given the history of a very similar occurrence at a still earlier period, a few miles south of this. It is related by him, that "about a mile from Combermere abbey, part of a hill, with trees upon it, suddenly sunk down, and was covered with salt-water, of which the abbot being informed, caused it to be wrought; but the proprietors of the wiches compounding with him, he left off working." It is likewise added, "that this salt-pool still continued in his time, but that no care was taken of it."

It is further stated, that a few miles lower down the Weaver than Brickley, in Baddiley, and one or two adjoining townships, springs are met with variously impregnated with salt. Brinefield is, it is said, the name given to different inclosures in Baddiley. And where the river takes a northerly direction at Audlem, brine is, it is said, met with on each side of it, and may be found, on sinking near its banks, all the way from thence to the town of Namptwich. About the midway between the former place and Namptwich there is a farm, it is remarked, which still retains the name of Brine-pits farm, where salt was formerly manufactured. Also a little further down, brine was found, and salt made, on each side of the river, at Austaston and Baddington, as stated in King's Vale Royal. However, at the present time, it is asserted that none is manufactured until the town of Namptwich is reached, where a great many salt-brine springs present themselves. Continuing the same course down the river, brine is again found at Winsford. And betwixt Winsford and Northwich, attempts have been made to get down to it; but these have hitherto, it is said, been rendered unsuccessful by the quantity of fresh water which has been met with. It is stated to be again found at Lettwich, in the angle between the Dane and the Weaver rivers; at Northwich; at Witton, half a mile north of the former of these places, on a small brook of the same name, which falls into the Weaver at Anderton, a township about a mile below Northwich. Also at Barnton, a mile still lower down the river, a weaker brine has been found; and again at Saltersford, about a mile below the above place. Two miles still lower, in Weverham, brine has likewise been found, which was worked, it is said, as early as the time of William the Conqueror; but it does not appear, it is remarked, that any has been discovered below this place.

And in following the course of the little stream, the Wheelock, brine is, it is said, first met with at Lawton, on the very confines of the county; then three or four miles

lower, at Roughwood, in the township of Bechton; again at Wheelock; and, lastly, at Middlewich, where the Wheelock falls into the Dane. It is remarked that no brine has been found in the valley through which the Dane flows from Middlewich to Northwich: however, higher up this stream, in the vicinity of Congleton, some of the inclosures have, it is said, the name of Brine-field, Brine-hill, &c. whence it may be concluded, that brine has some time or other been discovered there in such places.

But though the places which have been noticed are the only ones where brine has been found, and works for its evaporation erected, there is little doubt, it is supposed, but that it might be met with in almost every part of the valleys through which the Weaver and the Wheelock rivers take their course, did not the fresh-water springs prevent the access to or the coming at it.

It is stated that the depth from the surface at which the salt-brine springs are found; the level they take when the stratum which immediately confines them is penetrated; and the abundance of the brine which they contain or afford, are extremely various. About the town of Namptwich, the brine is met with, it is said, about ten or twelve yards from the surface; and that in sinking for fresh water, it is necessary to do it with caution, in order that the brine may be avoided. It is noticed, that in sinking for the foundation of a bridge, some few years ago, just above this town, a very copious salt-brine spring was found about eight yards from the surface; and that the workmen were much incommoded by it. The brine-springs mostly rise near to the surface. When Winsford is reached, to which place the river Weaver is made navigable, the brine is found, it is said, at a much greater depth from the surface; and that it is generally necessary to sink from fifty-five to sixty yards before it is met with, when it is usually found in great abundance. It has its level twelve yards from the surface. Near Northwich it is stated to be found at a depth from thirty to forty yards, the springs being very fluent; and its level is about twenty yards from the surface. At Witton it is met with at about the same depth, and rises much to the same level, the springs being equally copious. However, through the whole of Anderton, the quantity of brine is said to be the most abundant; at the higher end of that township it is observed to be found about forty yards from the surface, and that the level is nearly the same as that at Witton. Somewhat lower down, it is said to be necessary to sink from fifty to fifty-five yards before it is met with. Still keeping the course of the river, at Barnton, about a mile below Anderton, on sinking sixty yards, and boring fifty yards below this, it is noticed, that a very weak brine was discovered, and that in small quantities only.

In tracing the different salt-brine springs along the little stream of the Wheelock, it is said to be found, that at Lawton they are met with about eighty-five yards from the surface, and have their level at seventy yards. The springs here, it is remarked, are much less copious than many of those on the Weaver. At Roughwood, the brine is fifty yards from the surface, and rises fifteen yards; the spring is by no means abundant, and it is often pumped dry. At Wheelock it is noticed to be found at the depth of seventy yards, and that it rises within thirty yards of the surface; the springs being very copious. At Middlewich, however, the brine is, it is said, at different depths, as from thirty-five to eighty-four yards; in one pit, in which it is found at seventy yards depth, it rises, it is said, to the surface. But, it is remarked, that the springs here are by no means so fluent, and are occasionally pumped until they are quite dry.

In regard to the discovery of the salt-brine springs in this

district, and the time when they were first worked, it is said that we are without any certain accounts. It is thought, however, that there can be little doubt, but that at a very early period salt must have been procured from the brine-springs which found their way to the surface. This, as has been seen above, is particularly the case with the springs in the vicinity of the towns of Namptwich and Middlewich; and it is known from Doomday-book, it is said, that, at the time of Edward the Confessor, brine-pits were wrought at all the wiches in this district. It would appear, however, it is observed, that, even several centuries afterwards, the art of making salt was very imperfectly understood in any part of this country; and that the quantity manufactured was very inconsiderable. And it is further stated, that Henry VI., having been informed that a new method of making salt had been invented in the Low Countries, by which it might be made more abundantly in this country than had hitherto been the case, invited John de Sheidame, a gentleman of Zealand, with sixty persons in his company, to come into this country, and instruct his subjects in the new method of making salt, promising them protection and encouragement. But whether they came, or what their improvements were, does not appear: however, it is probable that these were not of much importance, or that they were lost, as we find the Royal Society, soon after its institution, very intent upon improving the art of manufacturing white salt, and publishing, towards the close of the seventeenth century, the accounts or histories of several modes of making it; particularly Dr. William Jackson's account of the brine-springs, and the method of making white salt at Namptwich, in this country; and Dr. Thomas Rastel's account of the manufacture of it at Droitwich, in Worcestershire. However, these are conceived to be rather reports of the methods of manufactures then used, than suggestions of improvements. The salt made in this country was still, it is said, considered inferior to that made abroad; and what was manufactured in Cheshire was confined to the supply of its own consumption, and that of a few neighbouring counties or districts.

But the want of knowledge in the manufacture, and the supposed superiority of foreign over English salt, it is observed, attracted, in the beginning of the last century, the attention of the house of commons; and Mr. Lowndes, a Cheshire gentleman, received a reward from parliament, in consideration of his making known some improvements he was thought to have made in the manufacture of salt. Soon after which the late Dr. Brownrigg published his ingenious and philosophical work on "the art of making common salt," in which, in addition to a full and detailed account of the processes in the manufacture of it, at that time used, he suggested, it is said, a variety of alterations and improvements. Some of these were, it is observed, adopted, though not to the extent which was admitted of by the state of the manufacture. In consequence, however, it is thought, of these and various subsequent improvements, joined to the increased commercial spirit of the country, and the facility of communication with the port of Liverpool, by rendering the river Weaver navigable for vessels of considerable burthen from Northwich and Winsford, the manufacture of white salt in Cheshire, as well for home consumption as for exportation, has exceedingly increased in the course of the last century, more particularly towards the close of it; and the support of it is now become, it is thought, an object and matter of the first consequence, not only to the county itself, but to the whole nation.

Therefore salt-brine springs appear to have existed, and to have been wrought in this district, from the earliest periods of

the history of this country, while the discovery of the beds of fossil salt in it are only of late date. See *Rock-Salt*.

In regard to the origin and strength of these salt-brine springs, it may be observed, that the notions concerning the former were, it is said, extremely erroneous and absurd until the discovery of the beds of fossil salt; but that since that period, no doubt has been entertained that their saline contents are derived from the water of springs, or rain-water, coming upon, or penetrating down to the surface of these rocky beds, or the heads of the rock, as they are commonly termed, and thus effecting the solution of a certain portion of them with which they come in contact. With respect to the latter, the quantum of such solution, or the strength of the brine, various circumstances will, of course, it is observed, influence it; but most particularly, the extent of surface of the rocky saline bed, which is exposed to the action of the water; as the greater this is, the more completely the water and the rocky bed are brought into contact, the longer and more perfect the solution which takes place, and the stronger the brine or salt-spring. But, independently of such an immediate operation, the strength of the brine will, it is said, be varied by the manner in which any pit is worked, and the circumstances attending the raising of the brine; for if it be pumped up seldom, it will be found to be weaker than it would be, were it drawn up more frequently. Dr. Jackson found, that a quart of brine, when the pit had been drawn off three or four days, to supply five or six wick-houses, yielded an ounce and a half more salt than at any other time, when it had a rest of somewhere about a week. And it is said, that it has been noticed at several salt-springs, by Dr. Brownrigg, that the brine is much stronger at the bottom of the pits than near the surface; also in dry weather, than in wet; and when the pits are constantly drawn, than when little brine is taken out of them. The explanation of which is considered to be this, that the water which finds its way to the layer or bed of fossil salt, probably remains, in a great degree, at rest, until put in motion by raising the brine; while in this state, the portion of it which is in immediate contact with the rock becomes saturated; but acquiring at the same time a greater degree of specific gravity than it had as pure water, it thereby prevents the water above from sinking down so as to act upon the rock; and the sum of solution is consequently less than where the pit is frequently worked, and the rocky saline substance exposed to a more constant action of the water. This, it is observed, is particularly the case in such brine-pits as are not immediately connected with any others; and that the same observations will be applicable to those pits which have a communication; with this difference only, that the mode of working in one pit is to be taken into consideration in the effect produced on the strength of the brine in another, independently of its own particular operations. It is stated, that most of the pits in the vicinity of Northwich and Winsford in the above district, have such a communication at the rock-head, as is rendered sufficiently apparent by the brine in one pit having its level lowered, when another pit is at work at some distance. At the former place this has been further evinced, it is said, when the brine has found its way into the cavity of a rock-salt pit, an accident which has not unfrequently occurred. In such cases, it is observed, six or eight brine-pits, at the distance of nearly a mile from each other, have often been laid dry, and have continued so until the rock-pit has been filled, and the brine has again found its level. Even on some occasions, where the cavity of the rock-pit has been large, it is remarked, that four or five weeks have elapsed before this has been fully accomplished. The strength of the brine will also, it is said, be further

materially affected by the quantity of fresh water which finds access to it, either directly through the sides of the shaft out of which the brine is drawn, or by any fissures, cracks, or openings in the earth with which these are nearly connected. The proportion of salt which is held in solution, in such cases will, it is said, bear a ratio to the fresh water thus introduced, and to the subsequent opportunity this has of acting upon the rocky substance. These circumstances are therefore all highly necessary to be considered in the working of salt-brine springs.

In respect to the quantity of salt which a given portion of water, fully saturated, will hold in solution, very different estimates have been formed; which are supposed to have been caused by confounding given quantities of brine with the same measures of water, and the want of proper discrimination between the quantities of salt contained in the one, and that capable of being dissolved by the other; as well as from the different state of the salt used in making the trials, in which there may have been variations in dryness, and more or less of the water of crystallization. But the result of the most correct trials shews it to be not quite six ounces in sixteen of water, avoirdupois weight. In the forming of establishments for the making of salt from brine-springs, this is, of course, of material importance, as the first points to be considered are unquestionably the strength and purity of the brine which is to be employed. However, notwithstanding these circumstances, the advantages derived from several other adventitious ones may, it is said, render it better worth while to prepare the article from a weaker brine in one situation, than from a stronger one in another. The chief and most material point which has any influence in this business, after those of the strength and purity of the brine, is said to be the convenience which is afforded of water-carriage for sending away the manufactured material, and for the ready conveyance of fuel to the works. The expence and capability of supply of this last article are also necessary to be considered. And the fluency of the spring is another consideration which, it is noticed, Dr. Jackson has observed, "may be rich or poor, in a double sense; for a spring may be rich in salt, but poor in the quantity of brine it affords." The opportunity of strengthening a weaker brine with rock-salt, may likewise, it is said, render it more advantageous to work this, than a stronger brine differently circumstanced.

In respect to strength and purity, the greater proportion of the brines of the above district are concluded, from different trials, to possess them in a very superior degree; and that many of those which are less impregnated with salt, have rock-salt at no great distance from them, for affording the ready means of strengthening them; while the springs are in general copious, and fuel, especially coals, readily procured, though of late at a much more increased rate than formerly, notwithstanding the more extended navigation of the principal river, and every convenience of water-carriage furnished by a neighbouring canal.

It is further noticed that the workmen, or the *wallers*, as they are denominated from the bank or wall they raise by the salt rubbish round the pits, commonly make their estimate of the strength of brine from its specific gravity; a new-laid egg being their usual hydrometer, which sinks in pure water, but is suspended when the water holds a small portion of dissolved salt in it; and has a larger or smaller extent of its surface exposed, as the brine contains more or less salt in solution. They have also an instrument of the above kind graduated upward, like that for spirits, which is occasionally employed, the zero point of which is completely saturated or *leach* brine; however, by this,

it is said, they only know the comparative strength of the different brines, and are not enabled to ascertain the exact proportion of salt contained in any given quantity of liquor.

It is however stated, that, from the table in Watton's Chemical Essays containing the specific gravity of water impregnated with different quantities of salt, from the one-third down to the one thousand and twenty-fourth part of the weight of the water, by knowing the same sort of gravity in any brine, a pretty exact estimate may be formed of the amount of the salt it contains. The French, it is observed, employ Baumé's instrument for this purpose, as being, from its ready application, the most useful and convenient. And with the same hydrometer, nicely adjusted and regulated with every possible care in other respects, the writer found by his trials that the strength of several of the Cheshire brines was from 21.250 to 25.625 *per cent.* of pure salt, and in one instance from 25 to 26.566 *per cent.*; or that in an ale-pint there was contained from 4 oz. 15 dr. to 6 oz. 2 dr.; and in one case from 6 oz. to 6 oz. 6 dr.; and the proportion of earthy salts contained were from 6.25 to 2.500 *per cent.* Some of the brine-springs are noticed to have a greater specific gravity than that of a saturated solution of muriate of soda in pure water; which was found by the above hydrometer to be, when cold, 27.812 *per cent.* of the salt; an ale-pint of the London standard brail measure, containing 6 oz. 12 dr. By referring to the work the quantities will be seen minutely put down, with the names of the different brine-springs to which they relate, and many other interesting particulars.

And a comparison of the strength of the brine-springs in the above district, with that of similar springs in France, may be formed by the account given by citizen Nicholas, an associate of the National Institute, in a memoir on the national salt-works in the departments of La Meurthe, Jura, Daubs, and Mont Blanc; who was required, by a decree of the committee of public safety in August 1795, to visit such works, and collect all the necessary information concerning their actual situation, and the means of their improvement. It would appear, it is said, that there are three of these establishments in the first, as at Chateau Salins, at Moxenvie, and at Dieuze; two in the second, as at Salins, and Mont Morot; one in the third, at Arc; and two in the last, as at Montiers, or Mont Salin, and at Conflans. At the three first places, the brine pretty regularly contains, it is observed, from 13 to 14 *per cent.* of muriate of soda, though, after long pumping, it comes up stronger. At the two second places, the average degree of saltiness in the former is 11.86 of the hydrometer; and that of the latter from 13 to 8; of it. At the third place, the brine contains from 33 to 74 *per cent.* of the same salt. And in a particular trial with the brine at Chateau Salins, the result was, that one pound of water gave 1 oz. 7 gr. of pure salt; 25 grains of selenite; 75 grains of Glauber's salts; and 81½ grains of muriated lime and magnesia.

In respect to the *rent* of brine-springs, from Doomfday-book, it is said to appear that the king had formerly a claim on all those in the above county. That, in the time of Edward the Confessor, there was a brine-spring at Namptwich, and eight falterns betwixt the king and earl Edwin; of which the king bore two-thirds of the expences, and received two-thirds of the returns; the earl the other third. Besides, the earl had a faltern for the particular use of his own family: if, however, he sold any salt from it, the king had two-thirds of the receipts, the earl one-third. Several private individuals had also, it is said, falterns for the use of their own families; but if they sold any salt, a certain sum was paid to the king.

However, no right over these springs is now, it is said, claimed by the crown; they being solely the property of the owners of the land in which they are found. Few of them, however, are occupied by the land owners; they being commonly let out to tenants, either at fixed annual rents, without any restrictions as to the working of them, or at rents proportioned to the extent of the manufacture, and the quantity of salt produced.

In order to prepare the salt, the brine is raised from the pits in which it is found, by being pumped up into cisterns, or reservoirs formed near the works. In such situations as admit of the aid of a stream of water, it sometimes is raised by that means, as is the case at different places. Where such assistance could not be had, it was formerly the custom to draw it up by horses. However, in Camden's time horses were not had recourse to for this purpose, as he observes, that "at Northwich there is a deep and plentiful brine-pit, with stairs about it, by which, when they have drawn the water in their leathern buckets, they ascend half naked to their troughs, and fill them, from whence it is conveyed to the wick-houses." The demand for salt increasing, small wind-mills were in addition employed for this use; and as the consumption became still larger, a variety of inconveniences were experienced from trusting to so uncertain a machine, which ultimately led to the use of steam-engines, and consequently, at almost all the newly-erected works the brine is raised in this way.

It is noticed that the *reservoirs*, into which the brine is pumped up, are either large ponds, formed in clay, and mostly lined with brick, being capable of containing the consumption of several weeks; or they are wooden cisterns, pitched within, fit for holding the supply of it for the consumption of only a few days.

Though it has been seen that many of the brines contain very large proportions of salt, so as to be nearly saturated in some cases, they will all dissolve an increased portion of salt to some extent; and as it is of great importance in regard to the economy of fuel, to have the smallest possible quantity of superfluous water to evaporate, it is constantly an object with the manufacturer to have a fully saturated brine. In cases, therefore, where the brine is weak, or where there is the convenience of saturating a brine already strongly impregnated with salt, this is done by putting rock-salt in the cistern into which the brine is pumped, and permitting the liquor to act upon it until it becomes completely saturated. For this purpose a strong wooden frame is fixed in the cistern, at about half its depth, upon which the rock-salt is thrown; and the earthy residuum is occasionally removed from it, after the whole of the salt has been dissolved. Water slightly impregnated with salt, in other works, is also improved and brought to a perfect state of saturation in the same way.

From these reservoirs the brine is, it is said, drawn, as it is wanted, through wooden pipes, or by troughs, into the *evaporating* pans, which are now made of wrought iron; the dimensions of which vary considerably, but they are mostly in new works a great deal larger than those which were in use a few years ago; usually containing from 600 to 800 superficial feet, and in one or two instances nearly 1000 feet. Their form is usually that of an oblong square, having the depth of from 12 to 16 inches. Those of the first sizes have commonly three furnaces, of from six and a half to seven feet long, and from 20 to 24 inches wide. The grates from two and a half to three feet from the bottoms of the pans. The furnace-doors single; and none to the ash-pits. Each pan is mostly partitioned out, and has a separate *pan-house*, on the sides of which are long wooden benches, more than a yard wide, for placing the salt upon in conical baskets to drain, after it is taken from the pan; these houses being covered with wooden or slated roofs, with *cauvers* to let the steam pass freely away. See the work alluded to above, and the article SALT.

The very great difference in the dimensions of the reservoirs, the pans, and other things used at present, and those which were employed two centuries ago; strongly denote the vast increase and improvement of this manufacture.

The salt is prepared from the salt-brine springs, in the above districts, into *flowed* or *lump* salt, *large-grained flaky* salt, and *large-grained* or *fishery* salt, by several different ways, or rather by the application of different degrees of heat in the process; the first sort being produced by the highest, or that of two hundred and twenty-six degrees, and the last sort by the lowest, or that of from one hundred to one hundred and ten. The intermediate degrees furnishing the other two sorts of salt, as those of from one hundred and sixty to one hundred and seventy; and of one hundred and thirty to one hundred and forty degrees of Fahrenheit's scale. See *MURIATE of Soda*, and SALT.

Though the white salt made in the above district was, little more than a century ago, scarcely more than sufficient to supply its own consumption, as has been seen, the increase which has taken place since that time has been so great, on different accounts, that the quantity disposed of for home consumption in different places is stated to have been, from six of the works, from the 24th of May 1805 to the same date in 1806, no less than 663,637 bushels, or 16,590 tons 77 bushels, which paid a duty to government of 475,728*l.* 15*s.* And though the increase has lately been so very large, there is reason to believe, it is said, that it is still capable of considerable extension. See *Rock-Salt*.

SALT-Brine Pits, the shafts, pits, or openings from which the salt-brine is taken or raised. See the preceding article.

Saltpetre

SALTPETRE. See *NITRAT of Potash*, *NITRIC Acid*, *POTASSÆ Nitrat*, and *Nitrat of Potash*, under **SALTS**. Of the chemical and medical properties of saltpetre or nitre, a brief account has been already given under the articles to which we have above referred. It remains to detail, as concisely as possible, the natural history of this substance, the mode of its manufacture, and its uses in the arts. Nitre, as a natural product, may be found in two different repositories, the first of which is lime-stones, and the second vegetable soil. The first, a calcareous repository, is either a peculiar variety of secondary floetz lime-stone, or calcareous tufa, or chalk, or indurated marle. In these rocks it occurs as a thin granular crust, or an efflorescence of minute spicular crystals, overspreading the outside, and lining the inside of natural and artificial caverns, with which these rocks abound. Hence, as it has been conjectured, it might have derived its name of saltpetre, "*sal-petræ*," or rock-salt. Calcareous strata containing nitre are found in various parts of South America, in some districts of France, in the county of Bamberg, and at Hamburgh, near Wurtzburg. But the most celebrated repository of native nitre is the Pulo of Molfetta, in the province of Puglia, in the kingdom of Naples. This deep cavity, in form of an inverted cone, has within it, and branching from it, several excavations, natural and artificial, the strata of which consist of hard secondary lime-stone, abounding with the remains of organized bodies. At the time when the abbé Fortis directed the public attention to them, all these caves were lined with an efflorescent crust of nitre more than an inch thick, which, after being scraped off, was again renewed within a few days in constant succession. The substance of the rock, to the depth of a foot or more, was richly impregnated with the salt which might be separated by lixiviation, but at a greater depth no nitre was found, or at least boiling water did not afford it by dissolution. A piece of this rock, however, appears by the testimony of Dolomieu, after lying for two months in a dry cabinet, to have been covered with a thin crust of nitre. Klaproth and Pelletier, having analysed the nitrous crust of Pulo, obtained the following results :

Klaproth.	Pelletier.
425.5	407.5 nitre.
2.	muriated potash.
	26.7 muriates.
	20.8 sulphates, soluble in cold water.
254.5	96.7 sulphate of lime.
304.	410. carbonate of lime.
986.0	961.7
14.	38.3 loss.
1000	1000

Another repository of native nitre is vegetable soil. Of all countries of Europe, Spain is said to abound most with

this kind of soil. According to Bowles, nearly a third of the uncultivated lands in the eastern and southern provinces of this kingdom afford a rich supply of it by the following management. During the winter and spring the land is ploughed twice or thrice, to the depth of three or four inches; it is suffered to lie fallow the whole summer, and about the middle of the autumn, the soil having been thus fully exposed to the air, is lixiviated; and the liquor being boiled down in the usual manner, affords, in cooling, a quantity of nitre, mixed with from 20 to 40 *per cent.* of common salt. A considerable part of the soil in Lower Hungary is richly impregnated with nitre; and the water of several wells and springs, containing from two-thirds to four *per cent.* of this salt, is unfit for drinking. In India many of the lands, and especially those that lie in the valleys of great rivers, very much abound with nitre; and in the presidency of Calcutta alone, between 7000 and 8000 tons are annually manufactured. The saline efflorescence which covers the surface of the soil being swept off, is renewed every other day at particular seasons of the year: and that soil, in which the salt is less abundant, is raked up in small heaps, mixed with the scrapings of roads and cattle-stalls, and after being for a certain time exposed to the action of the air, lixiviated. The earthy residue is mixed with fresh earth, and after two years affords as large a produce of nitre as at first. Those nitrous soils, the acid of which is combined, for the most part, with lime instead of potash, and which, in the usual mode of treatment, yield but a small quantity of nitre, are rendered productive by the addition of wood-ashes: the carbonated alkali of the ashes and the calcareous nitrate of the soil mutually decomposing each other, and furnishing, in the result, carbonated lime and nitrated potash. Many of the soils in India, as well as those of China and other parts of Asia, require this alkaline addition. This is also the case with much of the soil in the Crimea and Ukraine. In many parts of the Crimea, those parts are selected that have been long uncultivated, and also those artificial parts that have served for burial-places and the sites of towns; and the soil being dug up, is mixed with about one-fifth, by measure, of wood-ashes, and lixiviated in perforated casks in the usual method: the liquor thus produced, after concentration by repeated lixiviations, is mixed with the mother-water of a preceding crystallization, and boiled down for 24 hours, removing from time to time the common salt and muriated potash that separate during the process: it is then transferred, while hot, into shallow coolers, in order to crystallize, which it does in 24 hours more. The rough crystals being drained, are again dissolved in water, and the product of the second crystallization is a nitre somewhat impure, and yet fit for the market. Four hundred cubic feet of the mixture of earth and wood-ashes afford 42lbs. of nitre of the first crystallization, which, by subsequent refining, is reduced to 39lbs.

After the adoption of fire-arms, the consumption of

nitre became proportionably great, and of course art and industry more actively employed in obtaining it. Different soils were attentively examined, and experiments were made for ascertaining their various products. In the course of these researches it was found, that the superficial soil of farm yards, of cattle-stalls, of cellars, of privies, and of other places long exposed to the vapours of putrefying animal matter, afforded, when mixed with wood-ashes and lixiviated, a considerable quantity of nitre. It was also found, that the plaster, mortar, and brick rubbish of old houses, might, by a similar treatment, yield this salt. In consequence of these discoveries, the several substances now enumerated were claimed by the crown in most of the countries of Europe, and granted to societies incorporated for the purpose of making saltpetre, and supplying the public magazines with this indispensable article. England and Holland supplied themselves from India and China, and therefore paid little attention for a short time to this kind of manufacture: whereas France, Germany, and the Northern states of Europe, encouraged it to the utmost of their power. At Paris these associations or companies were incorporated so long ago as the reign of Charles IX.; and regulated by several statutes. Their privileges were very extensive, and enforced with such rigour, that they became occasions of discouraging agriculture, and of promoting tyranny and oppression. They were allowed to appropriate to themselves all the nitrous soils and materials which they could find, without any adequate compensation to the proprietors. Accordingly the earthen floors of every out-house, and even of inhabited cottages, were subjected to their depredations, so that the people were thus deprived of their best manure; and moreover, every parish or district was under an obligation of furnishing a certain quantity of wood-ashes. These oppressive powers were entrusted by the crown with the farmers-general, whose inferior agents exercised them to their own pecuniary emolument, and to the grievous annoyance of such persons as were the subjects of their extortion. Nevertheless, the annual produce of nitre at the accession of Turgot to the ministry, is said to have scarcely exceeded one-half of its amount about half a century before his time. This able minister introduced a very useful reform in this department, restricted some of the powers which had been so much abused, and abolished others; and transferred the administration of this business from the farmers-general to a particular commission, of which Lavoisier and Clouet were leading members; and a considerable sum of money was placed at the disposal of the Royal Academy of Sciences, to be distributed as prizes by this body to the authors of the best memoirs in the preparation of saltpetre; and thus important and beneficial improvements were introduced in the construction and management of artificial nitre-beds, and the refining of their produce. By these means, the amount of nitre made in France was increased during the interval elapsed from the year 1775 to 1785, from 1,800,000lbs. to 3,500,000lbs. After the commencement and during the progress of the Revolution-war, the necessities of the state occasioned a great additional demand for this article; so that the ablest chemists of Paris directed their ingenuity and sedulous attention to this object, and their success was such, that the produce of nitre was more than quadrupled, and the art of preparing it attained nearly to perfection. From processes detailed under the articles *NITRIC* and *NITROUS Acid*, &c. it appears, that three conditions are requisite for the production of nitrated lime, which, by the subsequent addition of carbonated potash, affords nitre, *viz.* animal matter in a state of decomposition, atmospheric air, or rather the oxygenous part of it, and carbonated lime.

In Virginia, they prepare the floors of their tobacco-houses for attracting nitre: the method of making it in this way, by Mr. Jeremiah Brown, has been published in Virginia, by order of the trustees for the improvement of arts and manufactures, and, in England, by order of the Society for the Encouragement of Arts, Manufactures, and Commerce. See an account of this method in the *Annual Register* for 1763, vol. vi. p. 121.

The construction of artificial nitre-beds was first proposed by Glauber. Having turned his attention to several previous circumstances, he suggested the following plan for the formation of nitre, which we shall extract from Aikin's Dictionary.

"Let a large square wooden vat be made open at top, and with a perforated false bottom placed a few inches above the real bottom, and between the two bottoms let a pipe with a stop-cock be inserted, so as to discharge any liquor into a shallow open reservoir sunk into the ground just in the front of the vat: on the opposite side of the reservoir let another vat, similar to that already described, be placed, and, to complete the apparatus, let a pump be fixed in the reservoir, by which its contents may be transferred to either of the vats that the workman chooses. Every thing being complete, let the vats be filled with horses', cows', or sheep's dung, mixed with leaves or any dry vegetables: then draw a weak alkaline ley from quicklime and wood-ashes, and pour it into one of the vats till it stands a finger's breadth above the other ingredients. In about 12 hours' time turn the cock, and let the liquor drain into the reservoir, whence it is to be pumped again into the other vat, and after 12 hours more returned into the reservoir. In the space of a few days, the contents of the vats will heat and ferment strongly: no further care is required till the decline of the fermentation, which may be known by the cessation of the steam: the materials are then to be again drenched with the liquor in the reservoir for 12 hours, and when this is again discharged the fermentation will recommence. This method being pursued for ten or twelve months, (taking care to keep the vats filled with fresh portions of leaves and dung as the mats subside,) both the liquor and the contents of the vats will be found to be very rich in nitre."

"The above method of Glauber's," says Mr. Aikin, "deserves notice as the first attempt at the artificial manufacture of nitre, although there is little doubt that its success is greatly exaggerated, as is but too much the custom of this author. Another method proposed by the same chemist, and the success of which is better authenticated, is the following. Construct a vault of frame-work of any dimensions, and line it to the thickness of three or four inches with plaster composed of the following materials, *viz.* one part of quicklime, one of wood-ashes, and two of cows' or horses' dung, with a sufficient quantity of urine to work it up to a proper consistence. This plaster being carefully applied, is to be dried by a gentle fire to be made under the vault, a second coating of the same materials is then to be put on, and thus, by alternate drying and plastering, the vault is to be made two or three feet thick. Being now sufficiently strong, the wooden framing may be removed. The plaster, in proportion as it dries, is to be restored to a proper state of moisture by the application of urine, and in the space of a few months, more or less according to the warmth of the air and other circumstances, the whole inside of the vault will be covered with nitrous efflorescences: by degrees the plaster will be impregnated with nitre through its whole substance, at which time the vault being broken down, and its materials being duly lixiviated, a large quantity of nitre will be obtained.

This method was adopted in many parts of Germany with reasonable success, but, requiring much manual labour, was at length abandoned for more economical processes.

"In France the nitre-beds are composed of nitrous earth from farm-yards, stables, &c.; of street-sweepings, of mild calcareous earth, such as old mortar or plaster, chalk, tufa, or the sweepings of roads paved with lime-stone; of animal matter, such as night-soil, blood, refuse from the skinners and tanners, bones and other offal; of vegetable matter, such as straw and stable litter, leaves, saw-dust, spent tanners' bark, &c. These are all mixed in somewhat casual proportions, care being only taken that a sufficient quantity of calcareous matter is present; they are laid as lightly as possible in long beds or pyramids under covered roofs to protect them from the weather, and are kept duly moistened with putrid water or urine: by this management they yield every other year, by lixiviation, a considerable quantity of nitrated lime, which, by the addition of wood-ashes or potash, is converted into true nitre. The circumstance in which the French nitre-beds differ principally from those of Sweden and Germany is, that they scarcely ever contain wood-ashes, the requisite portion of alkali being added in a subsequent part of the manufacture.

"The proportion of nitre afforded by these artificial beds it is not easy to ascertain. In France, where the custom is to lixiviate once in two years, the produce may be estimated at from seven to twelve ounces of nitre from 100lbs. of materials: of this about half is nitrate of potash, and the rest nitrate of lime, requiring therefore the addition of potash to convert it into true nitre."

For the theory of nitrification, and particularly that of M. Thouvenel, we refer to the work now cited. Various methods have been practised for the extraction of nitre from the earths that contain it, and the purification of this salt.

The marley earth, frequent in China, Persia, and many parts of the East, is selected for working from places where it stands in barren cliffs, on hills facing the northern or eastern winds. The manner of their separating nitre from this earth is as follows: they dig large pits, which they coat over on the inside with a stiff and firm clay; this they fill half full of water, and into it throw the earth. When the water has stood some days to imbibe the salt, they draw it off into other pits, defended by slight walls on all but the north-east side. Here the sun exhaling the water, the salt which it had imbibed affixes itself to the sides of the pit in small, brownish, white, hexahedral, but very imperfect, crystals, which are what we receive from the East Indies under the name of rough nitre.

This is the way the greatest quantity of this salt is made; but it is also procured from divers other materials, and by many other methods.

The method of manufacturing saltpetre in Podolia, related by Dr. Wolf, is as follows: the earth or mould, which they make use of for this purpose, is of a deep black; and they make choice of a place for their operation not far from a spot rich enough in nitre to keep them constantly at work, at least during a whole summer, and such as can supply them with water and wood at an easy expence. The utensils used in this manufacture, are a large copper boiler, containing about sixty amphors of six gallons, or about 54lbs. of water each, which is fixed in the ground, with its brim level with the surface; 100 wooden tubs, with a hole bored near the bottom, each of which holds a car of earth, or about four or five amphors; two very large casks of about 100 amphors each; about thirty-two wide troughs or coolers, holding about an amphor each; and a sufficient number of amphors for fetching water.

In the manufacture, the first operation is to beat the nitrous earth to a coarse powder with iron spades, and to clear it of all hard substances. If it be very rich in nitre (indicated either by its fatness or its downy efflorescence), they mix with it some of a poorer sort, in equal quantity, but very black and old: and, lastly, they add ashes, commonly those of the ash, which most abounds, to the amount of about a fifth part of the whole, and mix them well together. If they have a quantity of urine at hand, they throw it in, but never any quicklime: they then put one car of the prepared nitrous earth into one of the tubs, fill up the vessel with cold water, and stir the whole well with a wooden staff; and after it has stood twenty-four hours, with occasional stirring, they suffer the ley to run out at the hole near the bottom, and put it into large casks. In this decoction of the nitre, what they call the *mother of nitre* is absolutely necessary. This is the inspissated lixivium remaining after the crystallization of nitre, which cannot itself be made to crystallize, and they keep it from one year to another. Of this mother of nitre, they pour one or two tubs into the boiler, to which they add the new ley, collected in the great casks, till the boiler is full, and keep the contents boiling near twenty-four hours. As soon as they perceive any marks of crystallization on the surface, they remove the ley, thus decocted and inspissated, into the thirty-two wooden coolers, and let it remain there twenty-four hours; in which time the crystallization being completed, they drain off the mother of nitre, and return it into the boiler. The crystals are taken out and dried; but as they never prove clean, they are again dissolved in clean water, filtered through a flannel bag, and boiled up again, in a less boiler, to a requisite thickness, and then crystallized again, which brings them to be fit for sale. In this manner, the process is repeated through the summer, till the winter's frost puts a stop to it.

The method formerly used in a considerable manufacture at Paris was as follows: M. Bouret, who makes every year from 35,000 to 36,000lbs., employs six men night and day, two rooms, twenty large casks, and three horses. The casks are half filled with old plaster, which is changed every time of pouring on water, and the lower half with wood-ashes, which are changed but once in five lixiviations. The water poured on soaks through both the plaster and ashes, and is five times passed through fresh plaster. It is then boiled down in a copper pan, so placed that the flame passes quite round its sides. The fire is made of wood. The lixivium, when properly evaporated, is set to crystallize, and the crystals to drain. The scum taken off in the boiling is thrown upon the plaster, which, the longer it lies in heaps, (wetted from time to time,) becomes the stronger; and likewise in proportion to the putrid matter thrown upon it. The plaster used in the buildings at Paris, is made of that gypseous earth called plaster of Paris, and found in the neighbourhood of that city. In general, no lime is mixed with it; and if this be the case, the nitre is neither so good, nor produced in so great a quantity. It is known when the old plaster is worth being collected and employed, by the saltish taste of it.

The first thing, in the process of extracting and purifying nitre, is to assay the earth. This is done by lixiviating a few pounds of it, and adding to the liquor thus obtained as much of a solution of common potash, of a known strength, as is sufficient to decompose all the earthy salts. From this assay, the quantity of alkali required is easily calculated.

The next process is the lixiviation; which is performed in the following manner. Several cart-loads of nitrous

earth are mixed as accurately as possible with the requisite quantity of alkali, either in the form of wood-ashes, or pulverized potash. Several large casks with perforated false bottoms are then filled with the prepared earth laid on very lightly; after which as much river-water is poured in as the vessels will hold. In two or three hours time the cock at the bottom of each cask is turned, and the liquor is allowed to drain out during the remainder of the day. The casks of a second series, charged with earth as before, are now filled up with the first lixivium, and after standing for a few hours, the liquor thus concentrated is drawn off in the manner just described. By a similar process on the third day a lixivium, thrice as strong as the first, is obtained, which is now sufficiently concentrated to be boiled down. The contents of each series of casks are lixivated twice more, and the weak solutions thus obtained are employed instead of water in the first and second lixiviations of fresh parcels of earth.

The boiling down and evaporation next succeed. The lixivium, containing nitrate of potash, the muriates of potash and soda, with probably a few other salts, and various earthy and other impurities, is put into a large boiler like a salt-pan, and heated nearly to ebullition; it is then clarified by the addition of bullock's blood, or a solution of glue, the impurities, as they appear on the surface, being carefully skimmed off: when no more froth rises of itself, a little lime-water is added, which coagulates the remainder of the blood and glue, and thus completes the clarification. It is now boiled for several hours, and the muriates of potash and soda, as they deposit, are withdrawn by a perforated ladle. When the liquor is so concentrated that a few drops crystallize readily on being dropped on a cold iron, it is laded out into a vat, where it remains half an hour to deposit the common salt and impurities still floating in it: hence it is transferred to large wooden or metallic crystallizing basins, where it remains close covered up during from three to six days, according to the temperature of the air; at the expiration of this period the fluid mother-water is poured out and returned to the nitre-bed, and the salt deposited in a confused crystalline mass of an opaque dirty white, is broken to pieces and set to drain, after which it is brought to market, or delivered in to the government-stores, as rough nitre, or nitre of the first boiling.

In order to refine the rough nitre, the ancient practice was to subject it to two more successive boilings and crystallizations; by this method, however, a very considerable proportion of the nitre was left in the mother-waters, no inconsiderable share was volatilized by the heat required for evaporating the solution when it had nearly acquired the due degree of concentration; and besides, a great expence both of time and fuel was incurred. The modern method of refining this salt was invented in France a few years ago, and is now considered as brought nearly to perfection. It is thus effected:

The rough nitre is broken to small fragments by wooden mallets, and is then put into a wooden tub, with 20 *per cent.*, by weight, of cold water; in this state it remains for six or seven hours, being occasionally well stirred up, that the water may have free access to every part. The water is now let out by a hole at the bottom of the vessel, and carries with it in solution all the deliquescent salts, and the greatest part of the muriates of soda and potash, together with some nitre. When the whole of the liquor is

drained off, 10 *per cent.* more of water is added, and well mixed with the nitre for an hour's time, when it is discharged in the same manner as the first. Lastly, 5 *per cent.* of water is poured in, and run off again almost immediately after. The nitre thus washed, after being well drained, is put into a boiler with half its weight of water, and boiled till a pellicle forms on its surface; the liquor is then discharged into a leaden cooler, and stirred about with rakes, till it is quite cold, by which manipulation the salt is deposited in small crystalline needles. It is now taken out of the liquor with a perforated ladle and well drained: after which it is washed with 5 *per cent.* of cold water, and again drained: being then spread out on a large table it dries in a few hours, and is lastly heated over a fire in large basins for two or three hours, at a temperature not exceeding 120° Fahr. taking care to stir it all the while; by this treatment it is perfectly purified, and brought to the consistence of fine sand, and is now ready to be manufactured into gunpowder. See Aikin's Dictionary.

The use of nitre is very extensive in medicine, in the arts, and in chemistry.

Dr. Shaw, on this occasion, observes, that if the medicinal virtues of nitre were to be enumerated, as they stand confirmed by sufficient experience, perhaps they would prove more numerous than those of any one known medicine besides. It is serviceable in the stone and stoppages of urine, in deliriums, malignant fevers, diarrhoeas, the small-pox of the confluent kind, &c. so as to prove almost a general remedy. And all these excellent qualities are in this salt joined to that desirable property of being innocent, or scarcely any way prejudicial to the body. The usual dose of nitre, among us, is from two or three grains to a scruple; though, in many cases, it may be given with safety, and to better advantage, in larger quantities. From some experiments on the effects of nitre taken internally, related in Mr. Alexander's Experimental Essays, it appears, that nitre has a power of almost instantly retarding the velocity of the circulation of the blood, and of surprisingly diminishing the number of arterial pulsations; and that its effects are much more powerful when newly dissolved in water, than when it has remained dissolved during some hours. As this difference must have proceeded from the cold which is produced by nitre during its solution, probably a much greater effect would be produced by procuring that solution in the stomach. For the various medicinal preparations of nitre, see NITRE, and the references under that article.

In chemistry, besides the nitrous acid obtained from nitre, which is one of its most powerful agents, nitre itself is also used in many chemical operations. And in the arts, its properties of detonating with bodies containing phlogiston, of accelerating their calcination, and especially the calcination of the imperfect metals, render it useful for the purification of gold and silver, when they are alloyed with other metals. As nitre is quickly and easily alkalisied, it enters into the composition of reducing fluxes, or of simple fluxes, to assist fusion and vitrification. It may also be employed by its detonation, to discover the presence of the inflammable principle in substances. But the most considerable use of nitre is for the preparation of gunpowder. See NITRE, NITRUM, NITRATE, and *Nitrate of Potash*, under POTASH.

Salts

SALTS, in *Chemistry*, a term formerly used to signify all sapid substances which were soluble in water. The acids were termed *acid salts*, *alkalies*, *alkaline salts*; and those sapid bodies not possessing either of those qualities, *neutral salts*. In the present state of chemical science, the term salt is confined solely to the compounds formed by acids with the alkalies, earths, and metallic oxyds; the

substance combining with the acid being called the base of the salt.

Neutral salts are those in which the ingredients are in exact saturation. (See *NEUTRAL Salts*, and *NEUTRALIZATION*.) And they are thus distinguished from those, strictly so called, that are formed by the combination of acids with alkalies, in which the properties of the one or the other predominate. When the acid predominates, the salt is designated by the syllables *super* being added to the appellation of the neutral salt, formed with the same acid and alkali; but when the alkali is redundant, the syllable *sub* is added: thus, carbonate of potash, with a redundancy of acid, is supercarbonate of potash; and with a deficiency of acid, subcarbonate of potash; and as there are two varieties of acids formed from the combination of the same base or bases with different proportions of oxygen, so it has been found also necessary to distinguish the salts formed with them by different terminations; thus the salt composed of *fulphuric* acid and potash is termed *fulphate* of potash, while that formed with *fulphurous* acid and the same alkaline base, is termed *fulphite* of potash. When the acid has the term *oxy* prefixed to its name, the same syllables are prefixed to that of the salt: thus, *oxymuriate of potash* denotes a salt composed of the oxymuriatic acid and potash.

The neutral and other secondary salts have very different degrees of solubility; but that of almost all of them is in-

creased by an augmented temperature, while their solution is for the most part accompanied with a diminution of temperature. They may be obtained unaltered from solutions by evaporation; and, if the process be slowly conducted, they form in regular crystallized masses, which have more or less transparency according to the quantity of water which they retain in their composition. Exposure to air, heat, and moisture, variously affect the appearance of crystallized salts. When they lose their transparency, and are covered with a white crust, or fall to powder, on simple exposure to the air, such salts are said to be *efflorescent*; if, on the contrary, they attract moisture from the atmosphere and become fluid, they are named *deliquescent*; and *permanent*, when the air has no effect on their crystals. The circumstance of a salt first melting in a moderate heat, then becoming covered with a white crust, and ultimately being converted into a dry opaque mass, is termed *watery fusion*; but when, instead of melting, it splits with a crackling noise, this effect is termed *decrepitation*.

The efflorescent and deliquescent salts should be preserved, and dispensed in well-stopped bottles; while those that are permanent will not suffer from being put up in paper.

The following abstract of Mr. Kirwan's table of the composition of salts, shews at one view the quantity of base, acid, and water contained in the salts medicinally used.

Names of the Salts.			Base.	Acid.	Water	State
Carbonate of potash	-	-	41.	43.	16.	Crystallized.
— of soda	-	-	21.58	14.42	64.	Dry.
— of ditto	-	-	59.86	40.05		Defecated.
— of lime	-	-	55.	45.		Natural.
— of magnesia	-	-	25.	50.	25.	Crystallized.
—, common magnesia	-	-	45.	34.	21.	Dried at 80°.
Sulphate of potash	-	-	54.8	45.2	—	Dry.
— of soda	-	-	18.48	23.52	58.	Fully crystallized.
— of ditto	-	-	44.	56.	—	Defecated at 700°.
— of magnesia	-	-	17.	29.35	53.65	Fully crystallized.
— of ditto	-	-	36.68	63.32	—	Defecated.
Alum	-	-	12.*	17.66	51.†	Crystallized.
Ditto	-	-	63.75	36.25	—	Defecated at 700°.
Nitrate of potash	-	-	51.8	44.	4.2‡	Dried at 70°.
Muriate of soda	-	-	53.	47.5		Dried at 80°.
— of ammonia	-	-	25.	42.75	32.25	Sublimed.
— of barytes	-	-	64.	20.	16.	Crystallized.
— of ditto	-	-	76.2	23.8		Defecated.
— of lime	-	-	50.	42.		Red-hot.
— of magnesia	-	-	31.07	34.59	34.34	Sensibly dry.
Acetate of potash	-	-	61.05	38.05		In foliated mass.

* Ignited.

† Of composition.

‡ Of crystallization + 19.24 in the base.

§ Aqueous 38.88 real.

|| Higgins.

See *NOMENCLATURE*, and the different bases of salts under which the salts are described.

The general plan of this work has been to treat of the salts, as understood by the last definition, under their respective bases. We find, however, that this plan has been deviated from in the articles *ALUMINA*, *BARYTES*, and *POTASH*. This being the case, we think this the most proper place in which to supply the deficiency, and refer to the respective bases for the rest.

Sulphate of Potash.—This salt has been called in medicine *sal polychrest*, and in the old chemical nomenclature, *vitriolated tartar*. It is formed by directly adding sulphuric acid to a solution of potash, till the mixture is neither acid nor alkaline, which will be the case when it does not change the colour of

infusion, or syrup of violets. This mixture on evaporation affords crystals, which are larger and more complete as the time in which the water is escaping. These crystals are in the form of short six-sided prisms, terminating in pyramids of the same number of sides.

The specific gravity of this salt, in its perfect state, is about 2.4. It does not possess much taste, which is rather bitter. It dissolves in sixteen parts of water at 60°, and in four parts of water at 212°. It is not changed by exposure to the air. When thrown upon burning coals it decrepitates, like common salt. Exposed to a strong heat in a crucible it melts. If charcoal, or, which is better, saw-dust, be present, it is speedily converted into a sulphuret of potash, called also *liver of sulphur*. Its composition by Dr. Wollac-

ton's scale is in 100 parts, 46 sulphuric acid, and 54 potash. By Dalton's numbers 45 acid, and 55 potash. These proportions agree very nearly with the analyses of Bergman, Kirwan, Wenzel, and Dr. Thomson. The latter makes it 42.2 acid, 50.1 potash, and 7.7 water. It would seem from the latter that this salt consists of an atom each of acid, base, and water. This would be in Dalton's numbers 34 acid, 42 potash, and 8 water, which is doubtless near the truth.

This salt is partially decomposed by the nitric and muriatic acids; and its solution is completely decomposed by muriate of barytes, muriate of lime, lime-water, oxymuriate of mercury, nitrate of silver, and acetate and superacetate of lead, which therefore cannot enter into formulæ with it. In medicine, it is deobstruent and cathartic. It is given with great advantage in the visceral obstructions to which children are liable, and in combination with rhubarb it has been found more useful than any of the other saline purgatives in jaundice and dyspeptic affections. It is generally given in the form of powder, in doses of from \times gr. to zvi , as it is intended to act as a deobstruent or a purgative. Its official preparations are, "*Pulvis ipecacuanhæ compositus*," L. E. D.; and "*Pulvis scammonæ compositus*," L. See POWDER.

Sulphate of potash with sulphur, formerly "*Polychrest salt*," is directed by the Edinb. Pharm. to be prepared by mixing well together, equal parts of nitrate of potash in powder, and sublimed sulphur, and throwing the mixture in small quantities at a time into a red-hot crucible. When the deflagration terminates, let the salt cool, and preserve it in a well-stopped glass vessel. This salt has a sensibly acid taste, and reddens infusion of litmus: it is almost wholly dissolved in equal parts of water at 60° ; and by exposure to the air, it is altogether converted into sulphate of potash. Its medical properties and uses are the same with those of sulphate of potash; but it is very rarely used.

Super sulphate of potash, or, agreeably to a more modern nomenclature, *bisulphate of potash*. Its name indicates that it contains two atoms of acid to one of potash. It is formed by heating a solution of 84 parts of potash and 42 of sulphuric acid, of the specific gravity of 1.85. It crystallizes into long six-sided prisms, having the appearance of needles. Its taste is sharp and acrid. It dissolves in about three (five Thomson) parts of cold water at 60° , and in its own weight of boiling water. It is not changed by exposure to the air. When heated in a platina crucible it fuses into a transparent fluid, but becomes white and hard on cooling.

The composition of this salt, as well by an experiment made by Dr. Wollaston, as by theory, will be 34×2 acid, 42 potash, and probably 16 of water. Its efficacy as a remedy is yet unknown.

Nitrate of Potash. See POTASSÆ NITRAS.

It is the rapid evolution of the elastic fluids, resulting from the decomposition of the nitric acid, by the agency of the inflammable matter, that constitutes the energy of gunpowder, and the report of the pulvis fulminans, for the manufacture of which, see GUNPOWDER, and FULMINANS Pulvis.

The very extensive consumption of nitrate of potash in the manufacture of gunpowder, has made it a desideratum in some countries to obtain it by some artificial means. The great supplies of nitre have been from those warm countries where it exists native in the common soil. It abounds in this state in Egypt, India, South America, and Spain. Some parts of the soil contain much more than others. Where it is found plentifully the earth is collected into immense piles and lixiviated, which dissolves the nitre, and any other soluble matter. This liquor is evaporated and the nitre ob-

tained in crystals. The first crystallization is always impure, and is called *crude nitre*. The pure nitre can only be obtained by repeated solutions and crystallizations. It has been the opinion of some philosophers that nitre has its origin in vegetables, because it is often found an ingredient in their analysis. Several parts, however, both in natural and artificial nitre-beds, go far to prove that it originates in the earths themselves, aided by the presence of atmospheric air, by the heat and perhaps the light of the sun.

The author of this article has been informed by a friend recently travelling in Spain during the last season, that in many parts of that country he found it difficult, and frequently impossible, to get a draught of water that was not impregnated with nitre, and in some places he found nitre in the soil. In the neighbourhood of Madrid, immense heaps of this soil were collected for the purpose of extracting the nitre from it. What, however, is the most remarkable, and which tends to confirm the opinion above given respecting its origin, is, that these heaps, in a few years after having been lixiviated, which must have removed all the soluble parts, became again capable of furnishing a similar quantity of nitre; and what still more confirms the above idea, this process had been repeated upon the same heap several successive times. It appears from this fact, that some sorts of soil are capable of furnishing nitre by merely being exposed to air in warm climates.

This salt has been formed in great abundance in France and Germany, by what are called artificial nitre-beds. These consist of long narrow heaps of a collection of animal and vegetable matter, mixed with calcareous and other earths. Sheds are thrown over these heaps to shelter them from the rain, and keep up their heat; and they are also kept at a certain degree of moisture, by occasionally throwing water upon them. This keeps up to a certain extent the putrefactive fermentation in the animal and vegetable substances. The heat which these generate may contribute much to the process, as well as furnishing potash for the nitre. It is supposed that the nitrogen afforded by the animal matter in its nascent form may be more fitted for forming nitric acid with the oxygen of the atmosphere than is the nitrogen of the atmosphere, which is only presented in its gaseous form. There is, however, no proof of this being the case, since we find nitre produced where no animal or vegetable substance is present. These beds afford nitre after being exposed a certain length of time. The heaps are sometimes turned over, which facilitates the production of nitre. The nitre, mixed with other salts, effloresces on the surface of the heaps, and is swept with brooms from time to time. These sweepings are collected and purified by lixiviation and crystallization.

The earth itself is also lixiviated at certain periods, and then re-exposed. In Switzerland these nitre-beds are frequently connected with stables on a large scale, to take advantage of animal excrement.

Many vegetables furnish nitre in considerable quantity, particularly those that are poisonous, or possessing much odour. The extracts made from hemlock, henbane, and quassia, in a length of time become covered with crystals of nitre. During the maceration of henbane in hot water, for the purpose of making the extract, the nitric acid of the nitre is to a certain extent decomposed; as nitrous gas may be collected in considerable quantities. Is it not probable that those plants which furnish more than an ordinary quantity of potash, such as wormwood and the ferns, may originally contain nitre, which is decomposed during their incineration, leaving the potash combined with carbonic acid?

Nitre is sometimes used in preserving meat, particularly hams. It is to the effect of this salt that the meat owes its

red colour. This colour is produced by the presence of the oxygen, or at least by the abstraction of carbon, precisely on the same principle that venous blood becomes red. The fresh cut muscle, which is of the colour of venous blood, soon becomes changed by similar exposure to the air, and also by the application of nitre. What corroborates this idea is the fact, that when too much nitre has been used upon meat, it acquires the exact flavour of nitrous gas, and the parts most susceptible of this smell exhibit the prismatic colours. See SALTPETRE.

Muriate of Potash.—This salt was, before the present nomenclature, called *regenerated sea-salt*; and in medicine it was called *digestive salt of Sylvius*. See POTASSIUM.

It is best formed by adding muriatic acid to the crystallized carbonate of potash, till the effervescence ceases. This solution, by slow evaporation, affords cubic crystals, which are the salt in a state of purity.

Its taste is bitter. The specific gravity of the perfect crystals is 1.836. It dissolves in three times its weight of water at 60°, and in a little less than two parts at 212°. It is slightly deliquescent in the air. When exposed to heat, like the muriate of soda, it decrepitates. At a red heat it melts, and at an increased temperature it sublimes in white fumes.

This salt, in the dry state, is considered by sir Humphrey Davy as a compound of chlorine and potassium; in its humid state, it is a compound of potash and muriatic acid. When in this last state heat is applied, the oxygen of the potash combines with the hydrogen of the muriatic acid, forming water, which is driven off, leaving what sir Humphrey has termed *potassane*, and what Dr. Thomson has called *chloride of potassium*, and what in the old language would be termed *muriate of potash*. This salt, in the dry state, according to Wenzel, is composed of 35 acid and 65 potash; and, from the authority of Rose, 34 acid and 66 potash. By Dr. Wollaston's scale, it is 36.5 acid and 63.5 potash. By Dalton's numbers, 22 acid and 42 base; or, in the 100, it is 34.5 acid and 65.5 potash. These accounts so nearly agree, as to leave little doubt of their accuracy. See MURIATIC ACID.

Hyperoxymuriate of Potash.—This salt was first discovered by Dr. Higgins, but Berthollet was the first who pointed out its constitution and particular properties. It has since been examined by Lavoisier, Van Mons, Fourcroy, Vauquelin, Hoyle, Chenevix, and others. The latter chemist has given a very able paper upon this class of salts, in the Philosophical Transactions for 1802.

This salt is prepared by passing oxymuriatic acid gas through a solution of one part potash to six parts water. For this purpose, the latter solution may be put into the bottle B. (See Plate XVII. Laboratory, fig. 9.) The retort, A, contains the materials for producing the oxymuriatic acid. The gas, on entering the bottle B, first forces the liquid up the tube into the bottle C, and then slowly follows it in bubbles. These are generally absorbed before they reach the bottle C. If this should not be the case, the remaining gas descends by the tube b to the bottle D, which contains a solution of potash similar to that in B. When the alkali is nearly saturated, the salt in question begins to precipitate in the form of brilliant scales, or plates. These are not perfectly pure, but, by dissolving them in about three times their weight of boiling water, the salt falls down in greater purity as the water cools.

The form of the crystals of this salt, although they appear in the form of thin plates when minutely examined, is found to be that of the parallelepiped, or rather obtuse rhomboids.

It has a cooling, sharp, and rather acid taste. It dissolves in 17 or 18 parts of water at 60°, and in $2\frac{1}{2}$ parts of

water at 212°. It is not changed by exposure to the air. When exposed to heat, it first undergoes the aqueous fusion. If the heat be increased, the salt is at length decomposed. A large quantity of oxygen gas escapes, equal to one-third of the weight of the salt, leaving behind two-thirds of muriate of potash.

Its action upon combustible bodies constitutes its most remarkable properties. When three parts of this salt and one of sulphur are smartly rubbed in a mortar, a succession of explosions take place, not unlike the cracks of a whip. These are attended with flashes of purplish light, and a smell of sulphureous acid. The same mixture laid upon an anvil, and struck with a hammer, gives a loud report. When phosphorus is used instead of sulphur, the effects are much more violent. Similar, but less striking, phenomena are observed, when this salt is mixed with charcoal, sugar, starch, or gum, and almost any other dry vegetable matter. When these mixtures are touched with concentrated sulphuric acid, inflammation instantly ensues. This effect is still more conspicuous, when the mixtures are projected into the acid. In these experiments, the greatest caution should be observed. In the detonations by friction, or percussion, the eyes and hands of the operator should be guarded. The mixture with sulphur sometimes explodes spontaneously. Similar detonations also take place with metals and this salt, particularly the more oxydable metals. These energetic properties suggested the idea of using it, instead of nitre, in the manufacture of gunpowder; but its property of exploding by friction, renders even the mixture of the materials too hazardous to be practised. In the very first attempt to form the compound, two individuals lost their lives.

This salt is decomposed by nitric acid, which disengages the oxygen and the oxymuriatic acid.

The dilute muriatic acid added to this salt, in a very small retort, disengages a peculiar gas, which was discovered by sir Humphrey Davy, to which he has given the name of *euchlorine*. See OXYMURIATIC ACID.

We shall best shew the constituents of this salt, as well as its particular analysis, by referring to the chemical changes which take place in its formation.

According to the new hypothesis, which sir Humphrey Davy and some other chemists have adopted, the salt in question consists of 1 atom of chlorine, 1 of potassium, and 6 of oxygen. Agreeable to the common opinion, it consists of 1 atom of muriate of potash, with 6 of oxygen; or 1 of muriatic acid, 6 of oxygen, and 1 of potash.

By the first opinion, 6 atoms of chlorine enter the solution of potash: 5 of these decompose 5 atoms of water, with the hydrogen of which they form 5 atoms of muriatic acid. These combine with 5 atoms of potash, forming 5 atoms of potassane, and 5 atoms of water. The 6th atom of chlorine combines with 5 atoms of the oxygen derived from the water: these combining with an atom of potash, form an atom of the hyperoxymuriate of potash. If the atom of hydrogen be 1, oxygen 7, chlorine 29, and potassium 35; then 5 atoms of potassane will be $(29 + 35) \times 5 = 320$, and 1 atom of the hyperoxymuriate will be $29 + 35 + 42 = 106$.

By the old opinion, when 6 atoms of oxymuriatic acid enter the solution of potash, 5 of them give up their oxygen to the 6th. The first 5, which have become muriatic acid, combine with 5 atoms of potash, forming 5 atoms of muriate of potash. The 6th atom, with its 5 extra atoms of oxygen, combine with an atom of potash, forming an atom of the hyperoxymuriate. Here, oxymuriatic acid, as its name indicates, is supposed to be formed by 1 muriatic acid = 22, and 1 of oxygen = 7, being together equal to 29. The 5 atoms of muriate of potash will be $(22 + 35 + 7)$

$\times 5 = 320$; and the atom of hyperoxymuriate will be $(22 + 6 \times 7 + 35 + 7) = 106$, as before. We here see that both these theories explain the fact, and the result is the same in both, when the same elementary numbers are taken. From these data, the composition will be in a hundred parts,

Muriate of potash	-	-	60
Oxygen	-	-	40
			100

In classing this among the rest of the salts, we might presume the existence of an acid called the hyperoxymuriatic acid. This, however, has not as yet been obtained in a free state. The euchlorine of sir Humphrey Davy was at one time thought to be this acid; but since the latter is constituted by 29 oxymuriatic acid and 7 oxygen, while the acid united to potash, forming the salt in question, would consist of $29 + 5 \times 7$, such a supposition cannot be maintained. If the old opinion keep its ground, the proper name for this salt, agreeably to what has been laid down under NOMENCLATURE, would be *hyperoxymuriate of potash*. But if the new opinion prevail, it would be called, according to the nomenclature of Dr. Thomsen, *hyperoxychloride of potashium*.

Superphosphate of Potash.—This salt is formed by adding the liquid phosphoric acid to a solution of the crystallized carbonate of potash, till the effervescence ceases. By evaporation it assumes the form of a gelatinous mass, but does not crystallize. It has a sweetish-saline taste. When dry, its specific gravity is 2.85. It attracts humidity from the air, and is very soluble in water.

When heated, it first undergoes the watery fusion, afterwards becomes dry. The heat being raised, it melts into a transparent glass, which is deliquescent in the air. No analysis of this salt is known. By Dalton's numbers it is 46 acid and 42 potash, in 88 parts.

Phosphate of Potash.—This salt cannot be formed by directly adding the acid to the alkali, in a state of solution; as, in that case, the salt last described is always formed. In order to form the present salt, the superphosphate must be fused in a platina crucible with a quantity of alkali equal to that already contained in it. The white mass thus formed is the salt in question. The more certain way of forming this salt is to boil the alkali and the above salt together: a white powder subsides, which, being separated and dried, is the pure phosphate of potash. See *MURIATIC Acid*.

Fluide of Potash.—This salt may be formed by directly adding the liquid fluoric acid to potash, till neutrality is effected. Scheele says it does not crystallize; Wenzel, however, informs us that it does, when perfectly free from filix. It dissolves in water, and melts in a strong heat. See *FLUORIC Acid*.

Borate of Potash.—This salt may be formed by heating together nitre and borax (borate of soda). The nitric acid is driven off, and the potash decomposes the borax. By solution in water, and slow evaporation, the salt is obtained in crystals. According to the analysis of Wenzel, it is composed of 100 acid and 30 of potash. See *BORACIC Acid*, and *BORAX*.

Carbonate of Potash, or Pure Subcarbonate of Potash of the Edinb. Pharmacopoeia.—This salt is called salt of tartar, from having been formed by the calcination of tartar. When pure potash is exposed to the air, it soon attracts water sufficient to liquefy it, and also carbonic acid, ultimately becoming a solution of carbonate of potash. By evaporation it affords crystals, which require to be kept from the air to prevent their deliquescence. This salt may also be formed by deslagrating nitre with supertartrate of potash.

The composition of this salt has been very clearly made out by several able chemists. By Dr. Wollaston's scale, it is composed of 68 potash and 32 carbonic acid, in the dry state. By Dalton's numbers, of 19.4 acid and 42 potash; which in the 100 is 68.3 potash and 31.7 carbonic acid. See *CARBONATE of Potash*.

Subcarbonate of Potash. See *POTASSÆ Carbonas*.

Supercarbonate or Bicarbonate of Potash.—This salt differs from the last in containing twice as much carbonic acid. It is formed by adding carbonate of ammonia to the carbonate of potash, the salt last described, and distilling off the ammonia. The solution, by evaporation to a certain extent, and by slow cooling, affords crystals, appearing in plates lying one over the edge of the other. The most advantageous way of forming this salt is by passing carbonic acid gas through a strong solution of salt of tartar (carbonate of potash), in the apparatus, *Plate XVII. fig. 9.* (See *LABORATORY*.) The salt crystallizes without evaporation, the crystals being very large and well-formed.

This salt has a cooling taste, not the least caustic, nor scarcely alkaline. It dissolves in about four parts of water at 60°. When dissolved in boiling water, it seems to undergo a partial decomposition, as bubbles of carbonic acid escape; hence it should not only be formed in cold water, but dissolved in it, when used.

When this salt is heated to redness, it is completely converted into the carbonate of potash, having lost just half of its acid. From this fact, which has been mentioned by Dr. Wollaston, its composition will be obvious; being 68 potash to 64 carbonic acid, and *per cent.* 47 carbonic acid and 53 potash. From Dr. Wollaston's scale, it appears to consist of 2 atoms of acid, 1 of potash, and 1 of water. This will give *per cent.* 43 carbonic acid, 47.9 potash, and 9.1 water of crystallization.

Arseniate of Potash.—This salt is formed by adding arsenic acid to potash.

It does not crystallize. If exposed to the air in a dry state, it deliquesces.

When fused with a strong heat, it forms a white glass. If inflammable matter be present, the salt is decomposed by the metal losing its oxygen. The arsenic sublimes at the same time.

Superarseniate of Potash.—This salt, from its name, contains an excess of acid, probably twice as much. It is formed by adding more acid to the last salt. It crystallizes in quadrangular prisms. See *ARSENIC*, § 10.

The molybdate and chromate of potash are but little known.

Acetate of Potash.—This salt may be formed by adding pure acetic acid to a solution of carbonate of potash, till mutual saturation takes place. It is very difficult of crystallization, but it may be effected by a very slow evaporation. It has a sharp unpleasant taste. It is soluble in about its own weight of cold water. It becomes moist by exposure to the air. Like the rest of the salts, with vegetable acid it is decomposed by a strong heat, the residuum being charcoal and potash. See *ACETIC Acid*.

The London Pharmacopoeia directs it to be prepared by mixing together, in a large glass vessel, $1\frac{1}{2}$ lb. of subcarbonate of potash and a gallon of (diluted) acetic acid; and having evaporated the solution to one-half over the fire, by adding gradually as much more (diluted) acetic acid as may be necessary for perfect saturation. Let the solution be again evaporated to one-half, and strained; then continue the evaporation in a water-bath, so that, on being removed from the fire, crystals shall form.

Acetate of Potash of the Edinburgh Pharmacopoeia is pre-

pared by boiling one pound of pure carbonate of potash, with a very gentle heat, in four or five times its weight of distilled acetous acid, and adding more acid at different times, until, the watery part of the former portion being nearly dissipated by evaporation, the acid newly added occasions no effervescence, which will be the case after about 20 pounds of acid have been consumed; then evaporating slowly to dryness. Liquefy the remaining in pure salt with a gentle heat for a short time; then let it be dissolved in water, and filtered through paper. Afterwards evaporate this fluid, which, if the liquefaction be properly performed, will be limpid, otherwise of a brown colour, in a shallow glass vessel, with a very gentle heat; occasionally stirring the salt as it concretes, that it may the more quickly become dry. Finally, preserve the acetite of potash in closely shut vessels, to prevent its being liquefied by the air.

Acetate of Kali of the Dublin Pharmacopœia is formed by adding to any quantity of subcarbonate of kali, at different times, about five times its weight of distilled vinegar moderately heated: when the effervescence has ceased, and the fluid is somewhat evaporated, add, at intervals, more distilled vinegar, until the effervescence entirely ceases: then evaporate to dryness, and having raised the fire a little, cautiously liquefy the mass. Dissolve the salt in water after it is cold; filter the solution, and boil it, until, on being removed from the fire, it concretes into a crystalline mass, which should be very white. Put the mass immediately into close-stopped vessels.

Acetate of Potash has a slight peculiar odour, and a warm sharp taste. One fluid-ounce of distilled water at 60° dissolves 504 grains; or 100 parts of it are soluble in 105 parts of water, and in twice its weight of alcohol. In the watery solution it is spontaneously decomposed; and it is also decomposed by the strong acids, by a decoction of tamarinds, by the sulphates of magnesia and of soda, by the muriate of ammonia, the tartrate of potash and soda, and by solutions of oxymuriate of mercury, and of the nitrate of silver; which of course cannot enter into formulæ with it. See ACETIC ACID.

As to the medical properties and uses of this salt, it is mildly cathartic and diuretic; occasionally beneficial in febrile affections and jaundice, but principally used in dropsies, and other diseases requiring a copious discharge of urine. For producing the latter effect, the dose may be from ℥j to 3j, given every three or four hours, in any bland fluid. Doses of ʒij or ʒiij open the bowels. Its official preparations are "*Acetas hydrargyri*," E. D.; "*Tinctura acetatis ferri*," D.; and "*Acidum aceticum*," D. Thomson's Disp.

Oxalate of Potash.—This salt is easily formed by saturating a solution of the crystals of this acid with potash; and by adding a little excess of the alkali, the salt will be capable of crystallization. The crystals are long six-sided prisms.

Superoxalate of Potash.—This is formed in the wood sorrel, and is sold under the names of *salt of sorrel*, and *salt of lemons*, and is sometimes bought for lemon acid. It may be formed artificially, by dropping a solution of potash, by a little at a time, into a saturated solution of oxalic acid. The salt to be formed is so much less soluble than the acid, that as soon as it gets the proper dose of alkali to constitute the superoxalate, it falls to the bottom of the vessel in small crystals, which, when examined minutely, are small four-sided figures.

Neither of these salts have been analysed, but their proportions may be readily calculated, since the weight of the atom of oxalic acid is well defined, being about 40 times heavier than that of hydrogen. The first salt will, therefore, be 40 of acid and 42 of potash, or *per cent.* 49 acid and 51 base.

The superoxalate will be 80 acid and 42 base, or in the 100, 65.5 acid to 34.5 base. See OXALIC ACID, and OXALIS.

Tartrate and Tartrite of Potash. See TARTRATE and TARTRITE.

Supertartrate of Potash.—This salt exists in nature, particularly in the juice of the grape. It is generally collected from the sides of wine-casks, and may always be seen adhering to the sides of wine-bottles, when the wine has been kept for some time. This salt, when purified, is known by the names of cream of tartar and crystals of tartar. These, when well formed, are short six-sided prisms. It dissolves in 60 parts of cold water, and in half that quantity of boiling water. When exposed to heat it soon becomes black. This arises from the decomposition of the acid, the potash being left in the state of carbonate, since carbonic acid is one of the results of the decomposition. A portion of the acetic acid is also formed during this decomposition, which may be collected and mixed with some empyreumatic oil. This product was called pyrotartareous acid, but is now found to be acetic acid, mixed with the empyreumatic oil.

Tartrate of Potash.—This salt is known in medicine by the name of soluble tartar, to distinguish it from the last, which so sparingly dissolves in water. It may be readily formed, by adding to the supertartrate a solution of as much potash as it already possesses. This solution, by evaporation and gradual cooling, affords crystals in the form of four-sided prisms.

Its taste is rather bitter. It is soluble in almost four parts of cold water, and in much less of boiling water. It is decomposed by heat like the last.

The composition of the supertartrate, according to Bergman, is

Tartaric acid	77
Potash -	23

Or,

Tartrate of potash	56
Acid -	44

100

By the analysis of Thenard, it is

Acid -	57
Potash -	33
Water -	7

97

This last is probably near the truth; the first is very far from being so. See TARTRITE.

The nialat, gallat, benzoat, succinat, and saccolat of potash, are but little known.

Camphorate of Potash.—This salt is formed by adding camphoric acid to carbonate of potash, till carbonic acid ceases to be evolved. The solution on evaporation affords crystals.

This salt is soluble in four parts of boiling water, and in 100 parts at 60°. It dissolves in alcohol, which causes it to burn with a blue flame. See CAMPHOR.

The rest of the salts of potash are not known to possess remarkable properties.

Sulphate of Barytes.—This salt exists abundantly in nature under the name of ponderous earth, and *caulk*. From its insolubility in water, it cannot be formed artificially but in the state of white powder. In nature it occurs in crystals, in the form of transparent plates, or rather four-sided prisms, the bases being rhombs; the primitive form of the crystals

SALTS

being the same. To all appearance, it is the most soluble salt which has occurred. Boiling water dissolves more than half its weight, but cold water dissolves only $\frac{1}{10}$ th. Boiling sulphuric acid dissolves it, but it is precipitated by the addition of water. When exposed to the heat of 35° of Wedgewood, it fuses into an opaque glass or enamel. No single acid or base is capable of decomposing this salt, but the carbonates of potash and soda are said to decompose it by double decomposition. The most effectual way of separating the earth from it, is to expose it mixed with saw-dust, in a covered crucible, to a strong red heat for several hours. The sulphate is by this operation converted into a sulphuret, which is soluble in water. The sulphur may now be separated by weak nitre, or acetic acid, which dissolves the barytes. The acid may afterwards be driven off by a red heat. The analysis of Kirwan, which seems the most correct, is

Barytes	-	67
Sulphuric acid	-	33

Aikin makes it

Barytes	-	66.04
Acid	-	33.96

100

Dalton's numbers give the acid 34, and the barytes 63. This reduced to 100, gives

Barytes	-	66.75
Acid	-	33.25

100

See BARYTES.

Nitrate of Barytes. See NITRATE of Barytes, under which article the reader is desired to correct the number expressing its specific gravity, and to substitute 2.92.

According to Kirwan, its constituents are

Acid	-	32
Barytes	-	57
Water	-	11

By Dalton's numbers, this salt is composed of two atoms of acid, and one of base; and from the last analysis it would seem two atoms of water. These would make $2 \times 19 + 68 + 2 \times 8 = 122$. This reduced to 100, gives

Acid	-	31.1
Base	-	56.7
Water	-	12.2

Muriate of Barytes.—This salt may be formed precisely by the same directions as the last, using the muriatic acid as the solvent. The evaporation being now carried to a certain extent, the liquid may be set aside to crystallize. These crystals will be more complete by leaving the solution, slightly covered with a piece of gauze, to spontaneous evaporation. If a few crystals of the same salt are placed in the solution as soon as the crystallization begins, they will form needles for the new crystals, which may be obtained of great size. Under some circumstances the crystals are apt to become yellow, but the cause of this colour does not appear obvious. There is another method of preparing this salt, when the carbonate of barytes cannot

be procured, by first converting the sulphate, which is very abundant in the vicinity of most lead-mines, into a sulphuret, as directed in decomposing the sulphate of barytes, and adding muriatic acid to the sulphuret. This precipitates the sulphur, and forms muriate of barytes. This solution, filtered and evaporated, affords crystals of the salt. These crystals are in the form of plates, but when examined, they are four-sided prisms, with square bases.

It has a strong and disagreeable taste, and is said, like the rest of the barytic salts, to be poisonous. It is not altered by exposure to the air. It dissolves in about twice its weight of water at 60° , and is not much more soluble in hot water. Hence its crystallization is to be effected by a slow evaporation, rather than by a slow cooling. It decrepitates at the same heat that other salts do, and is not decomposable at the strongest heat. In the fused state it is considered, by the new doctrine, as a compound of chlorine and barium, which would in the 100 be 65.5 barium, and 34.5 chlorine.

In its crystalline state, Kirwan makes its composition to be

Acid	-	20
Barytes	-	64
Water	-	16

Fourcroy's analysis gives

Acid	-	22.93
Barytes	-	62.47
Water	-	14.6

Aikin gives

Acid	-	24
Barytes	-	60
Water	-	16

100

Dr. Wollaston's scale gives for the dry salt

Acid	-	26
Barytes	-	74

100

And the crystallized would be from the same

Acid	-	22.25
Base	-	63
Water	-	14.75

100

Dalton's numbers will give 22 acid, 68 base, and 10 water, which *per cent.* is

Acid	-	20.75
Base	-	64.1
Water	-	15.15

This salt is used only as a chemical test for detecting the presence of sulphuric acid, and in determining the proportion in which that acid exists in different bodies. See BARYTES.

The muriate of barytes is prepared, according to the directions of the Edinb. Pharm., by mixing together three parts of water, and one part of muriatic acid, and adding one part

of carbonate of barytes broken into small pieces. When the effervescence terminates, digest for an hour; then filter, and after due evaporation set the solution apart, that crystals may be formed; and repeat the evaporation as long as any crystals are formed. If the carbonate of barytes cannot be procured, the muriate of barytes may be formed in the following manner:

"Take of sulphate of barytes, two pounds; charcoal in powder, four ounces. Roast the sulphate, that it may be the more easily reduced to a very fine powder, and mix it with the powder of charcoal. Put the mixture into a crucible, and having fitted to it a cover, let it be exposed to a strong fire for six hours; then, having well triturated the matter, put it into six pounds of boiling water, in a glass or earthen vessel, and mix by agitation, preventing, as much as possible, the action of the air.

"Let the vessel stand in a vapour-bath until the undissolved part shall have subsided, and then pour off the liquor. Pour on the residue four pounds of boiling water, which, after agitation and subsidence, add to the former liquor; and then, while it is still hot, or, if it shall have cooled, after it is again heated, let muriatic acid be dropped into it as long as any effervescence is excited. Then let the solution be filtered and evaporated, that crystals may be formed."

Several other methods have been proposed for the preparation of this salt, the best of which is the following, recommended by Bouillon la Grange (*Annales de Chimie*, xlvii. 131.) Pulverize together equal parts of sulphate of barytes and muriate of lime; project the mixture into a red-hot crucible, and let the fire be continued till the whole be melted, which is then to be poured out on a heated tile. After it is cold, reduce the mass to powder; boil it for some minutes in six times its weight of distilled water, and filter the solution: then evaporate the liquor to a pellicle, and set it aside to crystallize. The crystals require to be re-dissolved and again crystallized, to free them from any of the calcareous muriate they may retain on the first crystallization. The Edinburgh process, however, is still preferable to this of La Grange, as the previous calcination reduces any metallic salts that may be combined with the sulphate; and being thus rendered insoluble, they are separated during the first solution of the sulphuret. Goetling advises muriate of soda to be added to the charcoal, by which a smaller quantity of charcoal is capable of reducing a larger quantity of sulphate of barytes. A mixture of one part of muriate of soda and two parts of muriate of lime is sufficient to decompose six of sulphate.

Muriate of barytes has an acrid, very nauseous, bitter taste. It crystallizes in grouped quadrangular tables, bevelled on the edges; transparent, white, and very brilliant; of a specific gravity of 2.8257; and not alterable from exposure to the air. When heated, it decrepitates, becomes opaque, and ultimately melts, but is not decomposed. One part requires three of water at 60° for its solution, and 2.20 of hot water. According to Kirwan, the constituents of 100 parts of this salt are, 64 of barytes, 20 of muriatic acid, and 16 of water. It is used only for forming the following solution, which is directed in the *Edinb. Pharm.* to be prepared by dissolving one part of the muriate of barytes in three parts of distilled water. This solution possesses all the chemical and medicinal properties of the muriate. It is limpid, transparent, and colourless; but is rapidly decomposed by the earthy, metallic, and alkaline sulphates and nitrates; the alkaline phosphates, borates, and carbonates, being precipitated in the form of a white powder. Its affinity for sulphuric acid is so great, that, as a re-agent, it is capable of detecting 0.00009 of that acid in any fluid.

This solution is stimulant and deobstruent, and in large doses poisonous. It was introduced into practice by the late Dr. Crawford as a remedy for cancerous and scrophulous affections; and its use was afterwards extended to syphilis. When taken in moderate doses, it appears to increase the secretion by the skin, augments the flow of urine, and improves the tone of the system; but by large doses, violent vomiting, purging, vertigo, and the most dangerous symptoms, are produced. It has undoubtedly been found beneficial in several instances of scrophula, in some cutaneous affections, and in ulcerations connected with elephantiasis; while in syphilis it has the power of suspending some of the symptoms for a short period. But although it be a medicine of some efficacy, yet, to use the words of Mr. Pearson, in whose opinion of its deficient powers as an antisyphilitic we place implicit faith, its "good qualities are uncertain in their operation, and narrowly circumscribed; nor is it a preparation on which great confidence can be placed for the cure of any disease." The dose requires to be carefully apportioned, and very gradually increased, until from ℥v, which are sufficient at first, ℥xx be taken twice a day; or more, if nausea be not excited.

It is sometimes used externally as an escharotic to fungous ulcers and specks on the cornea. Thomson's Disp.

Phosphate of Barytes.—The most simple process for forming this salt, is to add a solution of phosphate of soda to a solution of muriate of barytes. The acids exchange bases, and the phosphate of barytes is precipitated in the form of a white powder, having no taste. This salt is not soluble in water. Its specific gravity is 1.2867. With the heat of a furnace it melts into a white enamel. Its composition is not known by analysis, but by theory it should consist of

Barytes	-	74.5
Phosphoric acid	-	24.5

99

The phosphorous acid combines with barytes by treating phosphate of soda with the muriate of barytes. It is insoluble like the last, and has no very distinguishing characters.

Fluate and Borate of Barytes.—Little known.

Carbonate of Barytes.—This salt exists in nature in several parts of England. It was first discovered by Dr. Withering, and has been very improperly called *Witherite*.

The form of its crystals in the native state is various. It is found with double pyramids, sometimes with six and also with four sides. It also occurs in six-sided prisms, terminated by similar sided pyramids. It frequently appears like bundles of needles radiating from a point. Its specific gravity is 4.331. It is said to be soluble in $\frac{1}{100}$ of cold, and $\frac{1}{100}$ of boiling water. It is not altered by exposure to the air. Its composition, according to Withering, is

Carbonic acid	20
Barytes	- 80
	100

According to Pelletier, it is composed of

Acid	- 22
Barytes	- 62
Water	- 16

This salt may be prepared artificially by adding carbonate of potash to muriate or nitrate of barytes. The salt is precipitated in a white powder, which requires to be separated by filtering, washing, and drying. This powder is of the specific gravity 3.763. Its composition, according to Bergman, is

Acid	-	7
Barytes	-	65
Water	-	23

100

According to Kirwan, the ignited salt is

Acid	-	22
Barytes	-	78

100

By Dr. Wollaston's scale, it is

Acid	-	22
Barytes	-	78

100

By Dalton's numbers,

Acid	-	22
Barytes	-	78

There is in all probability a bicarbonate of barytes, which is much more soluble in water. This would consist of

Acid	-	38
Barytes	-	68

106

Arseniate of Barytes.—This is an insoluble salt, little known.

Molybdate and Chromate of Barytes.—Not known.

Acetate of Barytes.—This salt may be formed by dissolving the carbonate of barytes in acetic acid. By evaporation it affords crystals in the form of needles, which are six-sided prisms. It has an acid bitterish taste, and is soluble in water; it slightly effloresces in the air. See **ACETITE of Barytes.**

Oxalic acid in excess, added to barytes, constitutes a superacetate, which affords crystals, and is sparingly soluble in water. When neutral it becomes an insoluble powder.

Tartrate of Barytes.—Not known.

Citrate of Barytes.—Citric acid dissolves barytes, forming at first a white powder, but gradually assumes the form of silky flakes of a beautiful appearance.

Benzonate of Barytes is soluble in water.

The rest of the salts of barytes are at present but little known.

Sulphate of Ammonia.—This salt is formed by saturating carbonate of ammonia with sulphuric acid. By evaporation it affords crystals, which are six-sided prisms, terminated by six-sided pyramids. These are extremely small, like needles, when the evaporation is too rapid.

Its taste is sharp, bitter, and disagreeable. It dissolves in two parts of water at 60°, and in half that quantity of boiling water.

It becomes moist by exposure to the air.

When heated it decrepitates. If the heat be continued

it sublimes, losing a part of the alkali, and passing to the state of a super-salt. The heat at length favours the decomposition of the acid by the hydrogen of the ammonia, by which azotic gas is produced.

Its composition, according to Kirwan, is

Acid	-	54.66
Ammonia	-	14.24
Water	-	31.1

100

By Dalton's numbers, and supposing the salt to be constituted by one atom of acid to two atoms of ammonia, we have

Acid	-	74
Ammonia	-	26

See **CARBONATE of Ammonia.**

Nitrate of Ammonia.—This salt is formed by adding carbonate of ammonia to nitric acid till the effervescence ceases. On evaporation this salt crystallizes in long prismatic crystals, terminating in pyramids. To give them the latter form, the evaporation is made with a low heat, not more than 100°. When evaporated at the boiling point, the crystals assume a fibrous form. If the heat be still raised higher up to 250° or 300°, the mass on cooling assumes a compact form.

The taste of this salt is very acid and disagreeable. Its specific gravity is 1.5785. It is soluble in two parts of cold, and in half its weight of boiling water. It is deliquescent in the air.

When the crystals of this salt are put into a glass retort, and placed over an Argand lamp, it melts at about 100°. By keeping it in a boiling state, the water distils over, and the heat requires to be gradually raised in order to keep up the distillation. When the temperature reaches about 450°, a number of bright bubbles begin to appear on the surface, assuming a different appearance to that of the boiling of a fluid. These bubbles result from the decomposition of the salt, and are no other than the gas called nitrous oxyd, which comes rapidly over. The whole salt is, in this process, converted into water and nitrous oxyd, and ultimately the retort becomes empty. (See **NITROUS OXYD.**) The decomposition of this salt sufficiently points out its constituents, and admits of a simple explanation by Dalton's numbers. His number for nitric acid is 19, viz. 1 of azote \times 2, of oxygen 2×7 . His atom of ammonia consists of 1 of azote, 5, and 1 of hydrogen, 1, and the number for it will be 6. The nitrate of ammonia is therefore constituted by 1 atom of nitric acid, 19, and 1 of ammonia, 6. An atom of hydrogen in the ammonia combines with 1 of oxygen in the nitric acid, forming water, and the azote of the ammonia combines with the other atom of oxygen and azote of the nitric acid, forming an atom of nitric oxyd, which is constituted by 1 atom of oxygen and 2 of azote. The whole salt being made of 2 oxygen = 14, 2 azote = 10, and of 1 of hydrogen = 1, the whole being 25, the result will be $1 + 7 = 8$ water, and $7 + 2 \times 5 = 17$, the nitrous oxyd. Hence the salt will be *per cent.* without water,

Acid	76
Ammonia	24

100

The salt in prismatic crystals will contain an atom of water, and will then be, acid 57.5, ammonia 18.2, water 24.3; amounting to 100.

According to Kirwan's analysis, it is acid 57, ammonia 23, water 20; amounting to 100. See AMMONIA.

Muriate of Ammonia. See SAL AMMONIAC.

Phosphate of Ammonia.—This salt is prepared, like the last, by adding carbonate of ammonia to phosphoric acid.

By evaporation it forms crystals in the form of four-sided prisms, terminated by pyramids. When these are small they appear like needles. It has, like most of the ammoniacal salts, a sharp disagreeable taste.

It dissolves in two parts of water at 60°. It is deliquescent in the air.

When heated in a retort, the salt first parts with some ammonia, leaving the salt in the state of a super-salt.

The acid undergoes decomposition, probably from the hydrogen of the ammonia, as some phosphorus comes over dissolved in ammonia, and in the state of phosphuretted hydrogen. Ultimately all the ammonia is expelled, leaving the phosphoric acid in the state of glass.

There seems to be no accurate analysis of this salt.

Fluate of Ammonia.—This salt is obtained by saturating carbonate of ammonia with liquid fluoric acid. It crystallizes and sublimes by heat.

Subcarbonate of Ammonia.—To form this salt in a state of purity, let five parts of dry powdered chalk be mixed with three of muriate of ammonia, also very dry and in powder. Place the mixture in a crucible of close texture, having a groove round the top; let a dish-like or conical vessel of the materials be inverted over this, and filling the groove. This latter vessel should have a small hole in the top, with a stopper, to remove occasionally. Place the lower vessel in a gentle sand heat. The carbonic acid of the carbonate of lime combines with the ammonia of the muriate, forming carbonate of ammonia, which sublimes at the heat of boiling water. This salt condenses into a cake in the inverted vessel, having a crystalline texture. In this state it is sold in the shops, under the name of volatile salt.

It is of a fine white colour, having a strong smell of ammonia, and a slightly acid yet cooling taste. It changes most vegetable blues to green. Its specific gravity is 0.966. It is insoluble in alcohol, but dissolves in two parts of cold water, and is much more soluble in hot water. Boiling water volatilizes it. This last property has rendered it useful to pastry cooks. It is dissolved in the water or milk with which the paste is made. In the baking, the salt rises in vapour, and makes the pastry light and honey-combed. When exposed to the air, it soon loses its strong smell, and is converted into a salt, which contains just half the quantity of ammonia, and which is named *carbonate of ammonia*.

The composition of this salt has the appearance of being very irregular.

When newly formed its proportions are, by Dr. Wollaston's scale, carbonic acid 44, ammonia 56; amounting to 100.

When it has been exposed to the air till it has no smell, its composition will be, acid 82, ammonia 18; amounting to 100.

Bergman makes its constituents to be 45 parts of carbonic acid, 43 ammonia, and 12 water,—in 100 parts; by which there would appear to be seven grains of ammonia in excess; but sir Humphrey Davy has found, that the quantity of alkali varies according to the temperature that has been employed in the preparation: thus, when it is formed at a

temperature of 300°, it contains rather more than 50 per cent. of ammonia; but produced at a temperature of 60°, it contains only 20 per cent.

The carbonate of ammonia of the Lond. Pharm. is formed by pulverizing separately one pound of muriate of ammonia, and two pounds of prepared chalk, dried: then mixing them, and subliming with a gradually increased heat, until the retort becomes red-hot. The carbonate of ammonia of the Edinb. Pharm. is prepared by taking one pound of muriate of ammonia, and two pounds of softer carbonate of lime, dried, pulverizing each of them separately, mixing them, and subliming from a retort into a receiver kept cold. That of Dublin is formed by mixing muriate of ammonia, reduced to powder, and well dried, carbonate of soda dried, of each half a pound; putting them into an earthen retort, and subliming with a heat gradually increased into a receiver kept cold. This salt, notwithstanding the name by which it is designated in the respective colleges, is merely a subcarbonate. Subcarbonate of ammonia is decomposed by the acids, the fixed alkalies, barytes and lime, and partially by magnesia.

As an article of the *Materia Medica*, this salt is stimulant, antispasmodic, antacid, diaphoretic, and in large doses emetic. It is beneficially given in gout, hysteria, and dyspeptic affections, when much acid is present in the stomach; and in infantine convulsions connected with dentition, or with acidity of the primæ viæ. As a diaphoretic it is occasionally exhibited in chronic rheumatism, in combination with guaiacum; and sometimes, though rarely, it is employed to produce vomiting in gouty and paralytic cases. From the ammonia it contains in excess, the subcarbonate is applied as a local stimulant to the nostrils in syncope, hysteria, and languors; and with the addition of a little scent forms the common smelling salts of the shops. The ordinary dose is from grs. v to grs. xx, formed into pills, or dissolved in any aqueous vehicle; but to excite vomiting 3ʒs may be given for a dose, and repeated, if necessary, assisting its operation by plentiful dilution.

Its official preparations are as follow: viz. "Liquor ammoniæ carbonatis," or solution of carbonate of ammonia, which the Lond. Pharm. directs to be prepared by dissolving 8 oz. of carbonate (sub-carbonate) of ammonia in a pint of distilled water, and filtering through paper. The "Aqua carbonatis ammoniæ," or water of carbonate of ammonia, formerly water of ammonia, or spirit of sal ammonia, of the Edinb. Pharm. is formed by pouring 2 lbs. of water on muriate of ammonia and carbonate of potash, of each 16 oz. mixed and put into a glass retort; then distilling to dryness, from a sand-bath, with a fire gradually raised. The water of carbonate of ammonia of the Dubl. Pharm. is prepared, by distilling, with a fire gradually raised, 2 pints from a pound of muriate of ammonia, 28 oz. of carbonate of soda, and 3 pints of water. The specific gravity of this liquor is to that of distilled water as 1095 to 1000. This solution has the odour and taste of the concrete sub-carbonate; it is limpid and colourless; and when shaken with twice its bulk of alcohol, a coagulum, nearly uniform, is formed. Its medical properties and uses are the same with those of the concrete salt. It is given in doses of from fʒss to fʒj in any bland fluid.

Other preparations of the carbonate (sub-carbonate) of ammonia, are the London "Carbonate of potash," the "Carbonate of soda," (see CARBONATE, POTASH, and SODA,) the "Liquor ammoniæ acetatis," (see the next article,) and "Cuprum ammoniatum." The latter is formed according to the direction of the Lond Pharm. by rubbing together in a glass mortar half an ounce of

fulphate of copper and 6 drachms of subcarbonate of ammonia until the effervescence ceases; then wrapping up the ammoniacal copper in bibulous paper, and drying it with a gentle heat. The "Ammoniaret of copper" of the Edinb. Pharm. is obtained by rubbing thoroughly together in a glass mortar 2 parts of pure sulphate of copper with 3 parts of carbonate of ammonia, until the effervescence is finished, and they unite in a violet-coloured mass, which, wrapped up in bibulous paper, is dried, first on a chalk stone and afterwards with a gentle heat. It is preserved in a well-stopped glass phial. The Dublin Pharm. directs the ammoniated copper to be prepared by rubbing an ounce of sulphate of copper with an ounce and a half of carbonate of ammonia, in an earthenware mortar, until the effervescence has ceased, and they unite in a mass, which is dried, wrapped up in bibulous paper, or preserved in a phial closed with a glass stopper. See COPPER.

This preparation has the odour of ammonia, a hot, styptic, metalline taste, and a rich blue colour. Exposure to the air destroys the blue colour, and gives the salt a greenish hue. Ammoniated copper is tonic and antispasmodic. It has been principally employed in epilepsy, as a remedy for which it was first proposed by Dr. Cullen, and it has since been employed with advantage; though Mr. Thomson suggests from his own trials that it does not warrant any great dependence. The dose is gr. $\frac{1}{4}$, gradually increased to grs. v, given twice a day, either simply in pills of crumb of bread, or combined with valerian. The solution of ammoniated copper (Lond. Pharm.) is formed by dissolving a drachm of the copper in a pint of distilled water, and filtering the solution through paper; or the water of ammoniated copper (Dub. Pharm.) is prepared by mixing together 8 fluid-ounces of lime-water, 2 scruples of muriate of ammonia, and 4 grains of prepared verdigris, digesting for 24 hours, and pouring off the clear liquor. This solution is detergent and mildly escharotic; and it forms an useful local stimulant for cleaning foul indolent ulcers, and disposing them to heal; and it is also employed, still more largely diluted, for removing specks from the cornea. Thomson.

The arseniates, molybdate, and chromate of ammonia, are but little known.

Acetate of Ammonia. (See ACETATE of Ammonia.) Its crystals, which are difficult to obtain from the volatility of the salt, are in the form of needles.

It is capable, like the carbonate and muriate of ammonia, of being sublimed when its crystals are much more complete.

These are of a pearl-white colour. It has a sweetish cooling taste.

It is deliquescent in the air. It melts at 170° , and is volatile at 250° .

Its composition has not been determined with precision.

The "liquor ammoniæ acetatis" of the Lond. Pharm. is prepared by adding four pints of (diluted) acetic acid to two ounces of (sub) carbonate of ammonia, until the effervescence ceases. The "water of acetite of ammonia," (Edinb.) or "spiritus Mindereri," is formed by pouring on any quantity of carbonate of ammonia in powder as much distilled acetic acid as will exactly saturate the ammonia. The "water of acetate of ammonia" (Dubl.) is prepared by adding in small portions, with frequent agitation, $3\frac{1}{2}$ pints of distilled vinegar to two ounces of carbonate of ammonia, or as much as will saturate the ammonia, which may be ascertained by means of litmus. This solution is inodorous, has a slightly nauseous taste, and when made with pure materials, is limpid and colourless. It is decomposed by acids,

the fixed alkalies, the strong acids, oxymuriate of mercury, and nitrate of silver, which are therefore incompatible with the formulæ prescribing the use of it. As a diaphoretic it is in common use in febrile diseases, combined with opium, camphor, antimonials, or nitrate of potash. It is necessary to assist its determination to the skin with plentiful dilution, and a moderate degree of external heat; for by free exposure to cool air it excites the kidneys, instead of opening the skin. Externally, it is employed as a discutient; as a lotion to inflamed surfaces; and when diluted with rose-water holding in solution a small portion of opium, it is an excellent collyrium in chronic ophthalmia; and still more largely diluted, is occasionally used as an injection in the commencement of gonorrhœa. The ordinary dose is from f3ij to f3xij, given every three or four hours. Thomson. See AMMONIA, and SAL Ammoniac.

Oxalate of Ammonia.—This salt is formed like the last. It does not crystallize; it is employed in solution as a chemical test for lime.

Tartrate of Ammonia.—This salt has a cooling, bitter taste, and is very soluble in water. It is decomposed by heat. It combines with excess of acid, forming a salt of little solubility, similar to the supertartrate of potash.

SALTS, *Earthy*, are compounds of the acids with the pure earths, resembling the salts formed by the combination of acids with alkalies. Some of them are crystallizable, and soluble in water; others are nearly insoluble: some of them, considered in a medical view, exert scarcely any action in the animal economy; while others are possessed of great activity, and produce very striking effects.

The following Table, which we extract from "Thomson's London Dispensatory," shews the solubility of the above earths, and of the compounds which they form with acids.

Pure Earths.	Solubility in one Part of Water.	Acids which, in combination with these Earths, form		
		Soluble Compounds.	Compounds scarcely soluble.	Insoluble Compounds.
Lime	0.002	Nitric Muriatic Acetic Benzoic	Sulphuric Boracic	Phosphoric Carbonic Arsenic
Magnesia	0.000	Sulphuric Phosphoric Nitric Muriatic Acetic Benzoic Succinic	Boracic	Carbonic
Barytes	0.050	Nitric Muriatic Acetic Benzoic	Succinic	Sulphuric Phosphoric Carbonic Boracic Arsenic
Alumina	0.000	Sulphuric Nitric Muriatic Acetic Benzoic		Phosphoric Carbonic Boracic Arsenic

The following Table, extracted from the valuable work already cited, and formed on the more general table of Dr. Thomson, in his excellent "System of Chemistry," 4th ed. iii. 568, presents a synoptical view of the neutral salts with alkaline and earthy bases, employed as remedies, or for pharmaceutical purposes.

Salt.	Taste.	Figure of Crystals.	Action of Air.	Solubility in 100 parts of Water		Action of Heat.
Sulphate of barytes	None	Rhomboidal prisms	None	0.002	0	Decrepitates.
----- potash	Bitter	Six-sided prisms	None	6.25	24	Decrepitates.
----- soda	Bitter	Six-sided prisms	Effloresces	35	125	Watery fusion.
----- magnesia	None	Four-sided prisms	Effloresces	100	133	Watery fusion.
Alum	Astringent	Octahedrons	Little	5	133	Watery fusion.
Nitrate of potash	Cooling	Six-sided prisms	None	14.3	100	Melts.
Muriate of barytes	Astringent	Four-sided prisms	None	43		Decrepitates.
----- soda	Salt	Cubes	None	35.46	36.16	Decrepitates.
----- lime	Bitter	Six-sided prisms	Deliquesces	400		Watery fusion.
----- ammonia	Acrid	Four-sided pyramids	Subdeliquesces	31		Sublimes
----- magnesia	Bitter	Needles	Deliquesces	151		Watery fusion.
Hyperoxymuriate of potash	Cooling	Rhomboidal plates	None	6	40	Gives out oxygen.
Phosphate of lime	None	Six-sided prisms	None	0	0	Little.
----- soda	Salt	Rhomboidal prisms	Effloresces	25	50	Watery fusion.
Borax	Styptic	Six-sided prisms	Subeffloresces	5	16.8	Watery fusion.
Carbonate of barytes	None	Various	None	0.023	0.043	Little.
----- lime	None	Rhomboidal prisms	None	0	0	Decrepitates.
----- potash	Alkaline	Four-sided prisms	None	25	83	Watery fusion.
----- soda	Alkaline	Octahedral truncated	Effloresces	50	100 +	Watery fusion.
----- magnesia	None	Six-sided prisms	Effloresces	2		Decrepitates.
----- ammonia	Urinous	Irregular	None	50 +		Evaporates.
Acetate of potash	Hot	Plates	Deliquesces	99		Melts.
----- ammonia	Cool	Slender prisms	Deliquesces	Very soluble		Melts and sublimes.
Tartar	Acid	Irregular prisms	None	1½	3½	Melts.
Tartrate of potash	Bitter	Four-sided prisms	None	25		Melts.
----- potash and soda	Bitter	Eight-sided prisms	Effloresces	25		Melts.

SALTS, Metallic. See METALS, in the *Materia Medica*. The reader is desired to insert in that article, for Todd's London Dispensatory, Todd Thomson's, &c.

SALT, Bitter, Purgive, or Epsom. See SAL, EPSOM Salt, and Sulphate of MAGNESIA.

SALTS, Crystallizable, in Chemistry, distinguish and comprehend all saline matters susceptible of crystallization; in contradistinction to *fluor* SALTS; which see.

SALT of Colcothar is a white saline matter, obtained by lixiviating colcothar.

SALTS, Deliquescent, a denomination comprehending all saline matters, which may be obtained by crystallization, or drying in a concrete form, but which, when exposed to the air, imbibe its moisture, and lose their concrete crystallized form, deliquiating into a liquor by means of this moisture. See DELIQUESCENCE.

SALT, Diuretic. See SAL Diureticus, and ACETATE of Potash.

SALT of England, is a name given to a very rectified, concrete, volatile alkali obtained from silk; and also to the concrete volatile alkali obtained from sal ammoniac.

SALTS, Essential, include all concrete saline matters which preserve the smell, taste, and all other principal qualities of bodies from which they were obtained, which bodies are only vegetable or animal. The usual method of preparing them is by evaporating, to almost the consistence of a syrup, the liquors containing the essential salt, viz. the

expressed and depurated juices and strong decoctions, and by keeping them in a cold place. From many of these liquors, saline matters or crystals are deposited upon the sides of the containing vessels after a considerable time, and after they have undergone a kind of fermentation. These crystals, which are always very red, may be purified by dissolving them in water, filtering, evaporating, and crystallizing. These mineral salts are extraneous to the vegetables and animals from which they are obtained; and are procured in the same state in which they were introduced. The best known of these essential salts is *tartar*; which see.

SALTS, Fixed, a name given by many chemists to the salts obtained from the ashes of plants, which, not having been dissipated by fire, ought to be considered as fixed, in comparison of the other saline matters of these plants, which evaporate during their deflagration. As the saline substances remaining in the ashes of vegetables are entirely or chiefly alkaline, the name of fixed salt has become synonymous with that of *Fixed ALKALI*; which see. But other saline substances, as most neutral salts, which have not bases of volatile alkali, are nearly as fixed as fixed alkali.

SALT, Fossile. See ROCK-SALT and Common SALT.

SALTS, Fluor, distinguish and include all saline substances, which cannot by any method be rendered solid; such are nitrous and marine acids, volatile alkali altered by quicklime, and some others.

SALT, Fusible, of urine, called also *native* or *essential* salt

of urine, phosphoric salt, and microcosmic salt, is a neutral salt, composed of phosphoric acid, saturated with an alkali fixed or volatile.

It is best prepared from putrefied human urine; but it may be prepared from fresh. A quantity of the urine of sound beer-drinking men being putrefied in a moderate heat, and then slowly boiled in glazed earthen vessels to the consistence of a syrup; if this liquor be placed in a cellar or cool place, in about four weeks time, or sooner in winter, crystals of a peculiar figure will be formed. But these, being impure, must again be dissolved in a sufficient quantity of water, and filtered as hot as possible through grey paper, and the solution again put in a cool place, where, in a few days, crystals will again be formed much cleaner than the former. These being separated from the liquor and dried, the operations of solution, filtration, and crystallization, must be reiterated twice or thrice, till the salt becomes perfectly white and without smell.

Mr. Margraff says, that a hundred, or a hundred and twenty measures of urine, give about three or four ounces of this salt, which always crystallizes first, and is easily distinguished from that which appears afterwards in crystals of a long and cubical form.

This salt is ammoniacal, but of a peculiar nature. It is a saline acid body. By distillation an urinous volatile spirit first rises. The residuum may be reduced by a violent fire into a pellucid white transparent mass like glass, of a very fixed nature, and from which neither acid nor any thing else can be separated, without the addition of some other matter.

This vitreous substance may be entirely dissolved in two or three parts of distilled water, and is thereby changed into a transparent liquor, somewhat thick, not unlike the concentrated oil of vitriol, and having the properties of all acids, such as fermenting with volatile and fixed alkalies, forming neutral salts with them, precipitating bodies dissolved in alkaline menstrua, and dissolving alkaline earths. It does not dissolve gold nor silver: and copper, tin, and lead little, but iron very strongly. It extracts a red colour from *cochium pro ceruleo*, in German, *blau furben kobalder*, the mineral by which glass is tinged blue.

But this salt in its dry state attracts metals with much more vigour, and with them produces several remarkable and singular phenomena; for all which, as also for the relation their salt bears to acid, alkaline, and neutral salts, we refer to the learned author, who has also examined its effects on several solutions of terrestrial bodies. One most eminent property is, that mixed with the inflammable part of foot, and dissolved in a close vessel, it produces a phosphorus. An ounce of this salt of urine, thus separated from its urinous part, and exactly mixed with half an ounce of foot, affords in this way a drachm of the best phosphorus. The residuum did not produce any when tried.

The learned author does not pretend to determine exactly the true origin of this salt; he thinks its acid may come into the human body from vegetable aliments. He has observed elsewhere, that cresses, mustard, rocket, and even corn, exposed to a very violent fire, produce a phosphorus. Hence he thinks this acid must be mixed with those substances; and the like may happen in other vegetables. He thinks this conjecture strengthened, because urine in summer, when people eat most vegetables, always produces this salt in the greatest quantity. Margraff in *Mém. de l'Acad. de Berlin*, 1746. See also *Miscel. Berol.* tom. vii. p. 341.

Mr. Pott observes, that the figure of fusible salts varies much according to the heat, evaporation, and different mode

of crystallization; and that it assumes the shape of most others, as of saltpetre, vitriol, sal ammoniac, Glauber's salt, &c. but it is generally in shining, octagonal, prismatic crystals. The taste of this salt is cool, resembling that of borax, to which it is in other respects similar. When put on the fire in a crucible, it froths, swells, and melts. When melted upon a bit of charcoal, by means of a blow-pipe, it forms a round drop. The crystals of the second crystallization do also melt upon charcoal, when they are pure, but when cold they have a milky colour. They do not, like the crystals of the first crystallization, form phosphorus with phlogiston. They effloresce in the air, and are hot to the taste, in both which instances they also differ from the first crystals.

SALT of *Glass*, called also *Glass-gall*, is a kind of saline scum or mass, found in glass-house pots upon the surface of the melted glass. It consists of neutral salts, as common salt, vitriolated tartar, and others, which are contained in the soda and potash employed in the composition of glass, and which not being themselves susceptible of vitrification, are separated from the glass during the fusion, and collected together upon its surface, because they are specifically lighter. See GLASS, and SANDEVER.

SALT, *Glauber's*. See SAL, and *Sulphate of SODA*.

SALT of *Hartshorn*. See CARBONATE of *Ammonia*.

SALTS of *Count Lagarais*, a name by which the French and some other nations call a preparation of vegetable bodies, invented by the gentleman whose name it bears, but very improperly called by him a salt.

The history of these preparations is this: in the year 1731, the count de Lagarais shewed the French king some powders, which proved to be very useful in medicine, and which he called the *essential salts of certain plants*. The method of making these was long kept a secret, but at length, the discoverer publishing it to the world, it appeared that they were made by means of water only, agitated in a violent and continued manner in a close vessel with an instrument resembling a chocolate mill. Mr. Langelot had before attempted a resolution of this kind of vegetable, and other substances, by means of water and motion, but his was done by grinding them with a small quantity of water at a time; whereas this of the count's is by powdering the ingredients, mixing them with a large quantity of water, and breaking them to pieces by a continued motion of this sort of mill made with four vanes, or flaps of thin wood, which was kept for six or eight hours in a continual motion, by means of a larger wheel, such as the lapidaries polish stones with.

There is no doubt but that the instrument used by the count is of very great use, and that the result of the operation is a very valuable form of medicine; but it is not a salt, but an extremely fine extract, containing the gummy, resinous, and saline parts of the body, and in a form capable of being reduced to powder, and easily administered, as it contains the virtues of the plant it is made from, in an extremely small compass, and is capable of ready solution in aqueous fluids. It is certainly a form of medicine worthy to be brought into practice, and must be a very proper way of administering the more bulky medicines to children, and persons of tender constitutions.

To give a proper view of the nature of these preparations, and their difference from the extracts made in the common manner, it may be proper to enter, in some degree, into the manner of preparing the two forms. The common extracts of the shops are made either from the juices of succulent plants, as houseleek, purslane, or the like; or from a strong

decoction of the other drier plants in common water, which, when separated from the coarser parts by subsidence, filtration, or the like means, are evaporated over a *balneum Mariæ* to the consistence of a thick honey.

In process of time, an essential salt will separate itself from these extracts, and many plants have, in the decoctions, a large quantity of a fine substance, which will never be made to pass the filter; and the extracts, made by this means, contain the oil, the gummy and resinous parts of the plants, and the essential salts, though this is but in a very inconsiderable quantity. These are the common extracts of plants.

The method of making those extracts, called *count Lagarais's salts*, is this. They choose a glass vessel, capable of holding six or seven pints, and having a wide mouth; into this they put an ounce of bark, sassa, guaiacum, or any other vegetable of which they are to make the extract, first reduced to a coarse powder. They pour on this two pints and a half of rain-water, or distilled water, and then taking the vessel to the place where the mill is fixed, they raise it so high, that the body of the mill is in the middle of the liquor; then they cover the top of the vessel with a wet bladder, that the froth may not be thrown over, and then turning the large wheel, they make the mill move round very swiftly in the liquor for six or seven hours together; after this they let the liquor settle for an hour or two, till only the finer parts of the body remain suspended in it, and then pour it off into a number of flat China or stone-ware dishes, putting only a small quantity into each dish, and these they set in the sun, or over a *balneum Mariæ* prepared on purpose; for should they attempt the evaporation in a sand heat, the small quantity of extract in each dish would be burned. When the whole is evaporated to a dryness, there remains on the whole inner surface of the dishes a thin crust of an extract, which is to be separated by scraping it off with a piece of stiff paper, and reserved for use. This always breaks up in small scales, which have a very shining surface on that part where they adhered to the dishes, and it seems that this has given occasion to some to believe, that they were particles of real salt.

There is no doubt but this method of procuring a powerful extract might be of great use, in regard to all those substances which water can have power to penetrate; but it is not easy to give credit to its being able to make the like valuable medicines from the metals, though that has been pretended. Gold and silver are pretended to be operated on in a powerful manner by it, but there seems a fallacy in this, since even iron itself, which is much more penetrable by water than those metals, yields but little virtue to it; two ounces of the filings of this metal yielding, with the utmost care and accuracy, only about four grains of a white earthy matter, which is also much more likely to be a part of the water than of the metal.

The *salts of the metals*, as the count called them, which were prepared by this means, were always suspected to hold some saline quality, which they owed to the menstruum, which, whatever was pretended, was not simple water, and a strict examination of them always discovered a marine salt among them. It is true, indeed, that according to Langelot's method of grinding, some leaves of gold were reduced, by the addition of a very small quantity of water, into a liquor, from which, on distillation, a few red drops were separated; but it is to be observed, that as Langelot's method is the grinding of the substance with great vehemence, and for a long time, in an iron mortar, with a pestle of the same metal, there is reason to suspect, that

what was found to come forth in red drops was a solution of iron, not of gold, as was pretended by those who first prepared them.

It is not to be doubted, but the method of evaporation of count Lagarais's medicines is of great use, since no other can so well retain the finer parts of the medicines. Mr. Geoffroy tried it on roses, violets, and some other flowers, and found great reason to wish that all the medicinal extracts could be prepared in the same manner; but the method is impracticable, when medicines are to be prepared for general use; for though the mills might be made to be moved in great numbers at once, by a current of water, and so this part of the work performed with tolerable ease, yet the evaporations, in such quantities, could by no means be made in any tolerable room, or time, and they must be evaporated as soon as made, since they very quickly turn four, and lose all the virtues. *Mém. de l'Acad. Scienc. Par. 1739.* See EXTRACT.

SALT of Lead. See *Salt of LEAD*, and *SACCHARUM Saturni*.

SALTS, Lixivial, a general name given to all saline substances obtained by lixiviation of ashes, but particularly applied to *fixed alkali*.

SALT of Milk. See *MILK*.

SALT, Microscopic. See *Fusible SALT of Urine*.

SALT of Mineral Waters. See *HALCRYPTIUM*.

SALT, Muriatric calcareous. See *SAL muriaticus calcareus*.

SALTS, Neutral. See *NEUTRAL*, and the distribution of saline substances at the beginning of the article *SALTS*.

SALT, Neutral arsenical, is a combination of arsenic with fixed alkali to the point of saturation. M. Macquer first discovered this combination, and began an account of its properties in the *Memoirs of the Royal Academy* for 1746 and 1748. His method of making this salt, is, by mixing together equal parts of very white crystalline arsenic and purified nitre, and by distilling this mixture in a retort with a graduated heat, in the usual manner, till the retort is red-hot, and no more vapours of nitrous acid arise. In the retort there remains a saline mass, white, compact, and fixed; from which, after solution in hot water, filtration, evaporation, and crystallization, may be obtained beautiful, quadrangular, prismatic crystals, terminated at each end by a quadrangular pyramid, the sides of which correspond with those of the prism. This new salt is precisely neutral, and exhibits no marks of an alkaline quality. It is infinitely more soluble in water than pure arsenic, and dissolves in a less quantity of hot than of cold water. It is easily fusible by fire, and remains fused and transparent like glass, without being alkalized, if it has not touched any inflammable matter; for it may be easily decomposed by phlogiston, which unites with the arsenic, separates it from the alkali, and is sublimed. This salt cannot be decomposed by any pure mineral acid, because arsenic seems to have a greater affinity with fixed alkali than acids have; but when these acids are united with metallic matters, they can easily decompose the neutral arsenical salt, even by the humid way; so that a solution of this salt, added to a solution of metals, occasions a precipitate, composed of the arsenic and metal, while the acid of the metallic solution combines with the fixed alkali of the neutral, arsenical salt, and forms another neutral salt. Macquer's *Dict. Chemistry*, art. *Salt*.

SALT, Pine. See *PINE*.

SALT of Rochelle, or *of Seignette*. See *RUFELLENSIS Salt*, and *Tartrate of SODA* and *POTASH*.

SALT, Sea. See *Common SALT*.

SALT, Sedative, a name given by the modern chemists to a salt obtained from borax, by means of acids, of the virtues of which they boast much. Those who first described it, gave the process for making it in a very enigmatical manner; and their successors invented many different ways of preparing it. The truth is, that all mixtures of borax with the vitriolic acids furnish us with a sedative salt, as do all the mixtures of borax with spirit of nitre, or of sea-salt.

Becher first gave the enigmatic account of it, which Homberg traced to its origin, and found the way of making it with the vitriolic, as Lemery did with the other acids. This salt is formed by sublimation, and is a congeries of saline flowers, not a little approaching to flowers of benjamin. These flowers are so light and fine, that they swim upon water, and require a great quantity of water to dissolve them, and much more of cold than of boiling water; and, therefore, it may be crystallized by cold, and even by evaporation alone.

The sedative salt is a perfect *sal falsus*. It makes no alteration in the colour of the juice of violets, and has no sensible effect on the solution of corrosive sublimate, or on a solution of mercury in spirit of nitre for a long time; but it finally precipitates a yellow powder from it, as the borax does. There is this difference, however, between this precipitate, and that formed by crude borax, that the powder precipitated by the sedative salt does not, as the other, become white on washing with large quantities of water. These experiments shew this salt to be wholly analogous to tartarum vitriolatum, or to the Glauber's salts, in its effects.

When the composition of which this salt is to be made is placed on the fire, there arise different liquors before the salt appears; the first is a phlegm of a fatty complexion, and with the smell of soap; this is succeeded by a turbid white liquor, along with which there arise some of the first flowers. This makes a solution of mercury in spirit of nitre muddy after some time, and finally precipitates from it a small quantity of a white powder. After this all the salt or flowers ascend; these flowers, dissolved in warm water, recrystallize themselves in it when cold, assuming the same form with that they had in the flowers, except that the combinations of particles are more dense and heavy.

The usual method of making this salt by sublimation has been this. Take a glass retort, with a large neck; put into it four ounces of borax in fine powder, and pour on this half an ounce of common water, to wet it into a sort of soft paste; then add to this an ounce and two drachms of concentrated oil of vitriol; place the retort in a reverberatory furnace, and give at first a small fire, which raise by degrees till the retort is red-hot: there will pass over into the receiver about an ounce of aqueous matter; and after this the flowers, or sedative salt, will rise with a little more humidity; hence some part of the flowers will be dissolved in the liquor, and run over into the recipient, but the greater quantity will remain in form of a dry sublimation in the neck of the retort; they will finally stop up the whole orifice of the neck, and what arises after this usually forms a circle of a sort of glossy salt about their bases, out of which the flowers seem to shoot.

They are composed of multitudes of fine thin blades, or flakes, and are easily brushed out of the neck of the retort with a feather; the glossy circle at the bottom of them may be dissolved in water, and recrystallized, and by this means all the salt will be procured.

M. Geoffroy the younger has given, in the Memoirs of the Paris Academy, in 1732, an account of a way of making this salt by solution and crystallization alone, without the

trouble of distilling; he has also summed up the several other ways of making it with blue and white vitriol, but the method here mentioned is that by which the chemists now make it.

Geoffroy's method by crystallization is as follows: take four ounces of borax, and one ounce one drachm of the most concentrated oil of vitriol; put the borax into a glass retort, pour in it half an ounce of common water after the oil of vitriol, and expose the mixture to a fire gradually increased: after the phlegm has passed off, and even while it is passing, there arise flowers, or a volatile salt, in beautiful foliated laminae, some of which always melt by the heat of the fire; after the operation is over, the finest of the flowers are to be carefully gathered, and these are what stick to the neck of the retort. Those that are grey are to be thrown upon the remaining mass; this mass is to be dissolved in water, filtrated and evaporated gradually; sometimes, even without evaporation, the shining talcous laminae are to be seen in the liquor; after twenty-four hours standing, the water is to be poured off from these laminae, which are to be washed with fresh water, and then dried carefully in a warm place. If these crystals do not calcine in the place where they are put to dry, nor in the sun's heat, it is a sign there is nothing crystallized but the *sal neutrum*; if they do calcine, it is a proof that there is some Glauber's salt formed of the borax and the vitriolic acid, and crystallized in the mass. This sedative salt, obtained by crystallization, does not differ essentially from that which is sublimed, only that the crystals or laminae of the latter are more separated and detached than those of the former. This salt, when once it has lost its water by drying, cannot be raised into vapours by the most violent fire, in which it remains fixed, and melts into a vitreous matter, as borax does. Hence it appears that it is a saline compound, the principles of which are strictly united, and separable with great difficulty. This truth has been illustrated by numerous and accurate experiments on the subject, by Mr. Bourdelin, related in the Memoirs of the Academy for the years 1753 and 1755.

M. Cadet has also published in the Memoirs for 1766, an account of experiments on this salt.

Homberg, the inventor of sedative salt, believed that he discovered in it a sedative, antispasmodic, and even narcotic quality, and thence called it the narcotic salt of vitriol; it was, therefore, generally employed in convulsive diseases; but its sedative powers have not been well ascertained. See **BORACIC ACID**.

SALT of Soda, a name given to the marine or mineral alkali obtained from the ashes of soda, and of other maritime plants. See **KALI**.

SALT of Sorrel. See **Oxalat of Potash** under **SALTS**, and **OXALIS**.

SALT, Spirit of. See **MURIATIC ACID**.

SALT of Stahl, Sulphureous, a neutral salt, composed of volatile sulphureous acid, combined to the point of saturation with fixed vegetable alkali. This salt may be made either by saturating fixed alkali with volatile sulphureous acid, made in a cracked retort, in Stahl's manner, or by exposing linen, soaked in liquid fixed alkali, to the vapours of sulphur slowly burning. In the latter method, the linen dries, becomes stiff, and shines with many small needle-like crystals, which are the sulphureous salts. This has a more pungent taste than vitriolated tartar, is more soluble in water, and is crystallizable by cold. It may be decomposed by any acid, and its sulphureous acid expelled from it, and it is perpetually changing, from the constant dissipation (as former chemists suppose) of its phlogiston.

SALT of Sylvius. See *ACETATE of Potash*, and *SAL Marinus Regeneratus*.

SALTS of Tachenius, are impure fixed alkalies, obtained from the ashes of vegetables, burnt by suffocating their flame, and leaving no more communication with the air, than is sufficient for the burning of their most difengaged inflammable parts. The dried plant, in this process, is put in an iron pot, so heated, that its bottom may be red, and continually stirred, when a thick fume, and at length a flame, will rise from it. A lid must then be put on the pot, so loosely, that the smoke may escape but the flame be extinguished, and this lid must be occasionally removed for the convenience of stirring the plant. When it is thus reduced to ashes, the ashes must be lixiviated with boiling water; and when the lixivium has been evaporated to dryness, a saline matter, more or less reddish, will remain, which is Tachenius's fixed salt, and should be kept in a bottle. See the process described at large by Boerhaave, Chem. part ii. p. 28, &c. In this way of burning plants, the fixed alkali is phlogisticated, rendered semi-saponaceous, and mixed with all the neutral salts contained in the plants.

SALT of Tartar, the fixed alkali of tartar (which see); or this name is given to fixed vegetable alkali in general. See *CARBONATE of Potash*.

SALT, Vegetable. See *Soluble TARTAR*.

SALT of Vinegar, is a name given to vitriolated TARTAR, impregnated with very strong radical VINEGAR. See each article.

SALT, Vitreous, a term used by some modern chemists for a kind of salt, which till of late wanted a name, and which is found in, and separable from, the fixed alkaline salts of vegetables.

It is bitter, hard, fixed, and not alkaline, and of a crystalline, or glossy appearance.

The method prescribed by Boerhaave for the procuring it with the most ease, is this: put six pounds of the best pot-ashes into a clean glass, and add thereto twenty pints of cold rain-water; stir them together with a stick, and suffer the whole to rest. When the ashes are thoroughly dissolved, gently decant the clear lixivium, and there will be found at the bottom, mixed with the fæces, a number of small greyish granules, of a bitter taste, and of an almost glassy brittleness and hardness; these are the salt required, and contain no alkaline quality. But to obtain it in greater purity, dissolve six pounds of pot-ashes in four times their weight of water; filter the lixivium while hot, and make it perfectly clear; then put it into a glass vessel, ready heated and moistened, and suffer it to stand; a dusky crust will soon begin to shoot to the bottom and sides of the glass, and will gradually become thicker and thicker; at length, when no more appears to shoot, pour off the liquor, and there will remain behind a salt like the former, but purer, and in larger quantity; if the remaining lixivium be boiled a little, and set to crystallize again, it will afford a small quantity more of this salt, but after this it will yield no more, whence there seems to be only a certain and determinate quantity of this salt contained in the alkali. If this salt be put into a vessel of rain-water and shook about, it does not dissolve, only the alkali washes off, and the salt remains purer than before; after this it is to be gently dried and kept. Boer. Chem. pt. ii. p. 42.

It is well known among the chemists, that genuine fixed alkaline salts can hardly be crystallized; and though some have produced this salt as a crystallized alkali, the fallacy of the pretext is evident, since this appears on trial to be no alkali at all; and it remains not less difficult than before

to crystallize pure alkali, though a salt, different in its nature from it, may be crystallized in a certain quantity from among it.

This vitreous salt never runs spontaneously in the air, nor does it easily dissolve in cold water; when boiled, it requires a large proportion of water to dissolve it, and as soon as cold, it easily separates itself from it again; it is lastingly bitter to the taste, and crackles very much when thrown into the fire; it is neither acid nor alkaline, nor approaches in its nature to any other salt hitherto known, but seems nearest of all others to resemble sandiver. This may suggest a query, whether the fire in producing the fixed alkali, does not at the same time produce this salt from vegetables; and whether, by combining the sand and alkali together in glass-making, the fire does not again separate and throw up this salt in sandiver. Something of this kind seems to be the case, and a close inquiry on these principles may shew us why tartar, in the state of an alkali, does not afford this salt; for tartar proceeds from a subtil liquor, intimately fermented in all its parts. There yet remains the trying of this salt on various bodies, by means of fire, to give a true knowledge of its nature, which is at present too little known. This is to be observed, however, that it differs so much from the alkali in which it is contained, that the careful chemist, before he makes use of that alkali in any nice process or experiment, ought carefully to separate this neutral salt from it. Boerhaave's Chem. part ii. p. 100.

SALT, Volatile, a name commonly given to volatile, concrete, alkaline salts, as *volatile sal AMMONIAC*, and *volatil salt of hart's-HORN*. See also *Volatile Salt of AMBER*.

SALTS, Urinous, a term synonymous with alkaline salt.

SALT of Steel, a name given to several combinations of iron with acids; hence Riverius's salt of steel is a martial vitriol, made with iron, vitriolic acid, and spirit of wine.

SALTS microscopically examined. Mr. Leeuwenhoeck has opened a very extensive field for microscopic observations, in the evaporation of certain fluids, in which salts of various plants, and other substances of the like kind, had been dissolved.

The fixed salts, in general, are said by chemists to admit of no crystallization at all; but this curious observer found, that, on being evaporated in small quantities before the microscope, they each would shoot into extremely minute, but regular crystals, and those often of various forms in the same salt; but that these varieties were only of a certain number, and that no other salt but that to which they belonged had them all in the same regular manner.

The sophistications of salts, too common among our chemists, may be discovered by this means, and many other advantages may be obtained from it, as well as great amusement in the observation of the variety and beauty of the figure.

The most agreeable way of examining these salts, is by the solar microscope; but the most accurate and fittest for making deductions from, is that by the common double microscope. The way is to dissolve a small quantity of salt, of any kind, in water, and add to this about one-fourth part of spirit of wine; this renders the whole a much less fit menstruum for keeping the salt in solution, and consequently it much more readily concretes from among it. A large drop of this liquor is to be laid on the surface of a thin and clear piece of glass, such as may conveniently be laid upon the stand for receiving objects in this microscope: then this glass is to be held till gently heated over a clear fire, and when it begins to evaporate, the glass is to be placed under

the microscope, and about a third magnifier used to examine it. The salts will soon be seen beginning to shoot, and will form themselves under the eye into very beautiful figures; some resembling branches of trees, others ruins and fortifications, and the like; but what are most to be depended upon, as essential to the salt, are certain little single shoots, resembling crystals; these are determinate in their figure, the others more vague and uncertain. These will always be produced the same from the same salt, the others scarce twice from even the different drops of the same solution, alike in all respects. Phil. Trans. No. 172. p. 1075. See *Table of Microscopic Objects*.

Saw

SAW, SERRA, an instrument serving to divide into pieces divers solid matters, as wood, stone, marble, ivory, &c. The saw is one of the most useful machines, in the mechanic arts, ever invented. The fable which is perhaps founded on some surer tradition, attributes the invention of it to Icarus, who, vying with his father Dædalus, enriched the rising arts with several discoveries. It is added he took the first hint from the spine or back-bone of a flat fish, such

as the soal. The saw is made of steel, with teeth; but those differently filed, and turned, according to the use it is designed for. There is also a kind of saws without teeth, used in the sawing of marble, and other stones.

The best saws are of tempered steel, ground bright and smooth: those of iron are only hammer-hardened; hence, the first, besides their being stiffer, are likewise found smoother, than the last. They are known to be well ham-

mercd by the stiff bending of the blade ; and well or evenly ground, by the bending into a bow.

The edge, in which the teeth are, is always thicker than the back, in regard the back is to follow the edge. The teeth are cut and sharpened by a triangular file ; first fixing the blade of a saw in a whetting block.

When filed, the teeth are to be *set*, that is, to be turned alternately askew, or out of the right line, to make the wider kerf or fissure, that the back may follow the better. This is done by putting an instrument, called a *saw-wrist*, between every other two teeth, and giving it a little wrench, which turns one of the teeth a little towards you, and the other a little from you. The teeth are always set ranker for coarse cheap stuff, than for hard and fine ; because the ranker the tooth is set, the more stuff is lost in the kerf ; and if the stuff be hard, the greater is the labour of sawing it.

The workmen who make the greatest use of the saw, are the sawyers, carpenters, joiners, ebonists, stone-cutters, carvers, sculptors, &c. The lapidaries too have their saw, as well as the workers in mosaic ; but these bear little resemblance to the common saws.

But of all mechanics there are none who have so many saws as the joiners ; nor of so many different kinds. The chief are as follow :

Pit-saw, a large two-handed saw, used to saw timber in pits. It is set rank for coarse stuff, so as to make a kerf or fissure of almost a quarter of an inch ; but for finer stuff it is set finer.

Whip-saw, which is likewise two-handed, used to saw such large pieces of stuff as the hand-saw will not easily reach.

The *Hand-saw* is made for a single man's use ; of which there are various kinds ; as the

Ripping-saw, *Tenon-saw*, *Sash-saw* : the two latter are stiffened by a narrow back of iron, as they are made very thin for fine work.

The *Two-hand*, or *Cross-cut saw*, is much longer, and is used by two men.

The *Frame-saw* is a thin saw surrounded by a wooden frame, in which it is stretched very tight, to prevent its bending : it is used in a pit for cutting deals and vineers.

The *Compass-saw*, or *Turning-saw*, which is very narrow, has its teeth not usually set out of a right line, like the above ; but the cutting-edge is made thick, and the back thin, that it may freely be turned in a circular or compass-kerf.

The *Hack-saw* is made of a scythe jagged at the edge, and used for cutting off iron bolts.

Sawing

SAWING, the application of the saw, in dividing of timber, &c. into boards, &c.

There are wind-mills and water-mills which do the office of sawing wood, with infinitely more expedition and ease than is performed by the hand. They consist of several parallel saws, which are made to rise and fall perpendicularly, by means of one of the grand principles of motion. A very few hands are here needed, *viz.* only to push forward the pieces of timber, which are laid on rollers, or suspended by ropes, in proportion as the sawing advances. These mills are frequently used abroad; and have been also introduced in England; but the parliament, in consideration of this, that they would spoil the sawyers' trade, and ruin great numbers of families, thought fit to suppress them.

The mechanism of a sawing-mill may be reduced to three principal things; the first, that the saw be drawn up and down as long as is necessary, by a motion communicated by water to the wheel; the second, that the pieces of timber to be cut into boards be advanced by an uniform motion to receive the strokes of the saw, for here the wood is to meet the saw, and not the saw to follow the wood, therefore the motion of the wood and that of the saw ought immediately to depend the one on the other: the third, that when the saw has cut through the whole length of the piece, the whole machine stops of itself, and remains immoveable, for fear, lest having no obstacle to surmount, the force of the water should turn the wheel with too great rapidity, and break some part of the machine.

M. Felibien mentions a kind of long saws, invented by one Mifson, inspector of the marble quarries in the Pyreneans; by means of which stones are sawed even in the rock itself, whence they are taken. He adds, that some of them were made twenty-three feet long; but does not describe either their form or application: he only says, they are of iron, and without teeth.

The common sawing-mill is so well known, as to require scarcely any description. The saw is made to work vertically, being stretched in a wooden frame, which slides up and down, within another fixed frame, exactly the same as a window sash rises and falls in its frame: the motion is given to it by a crank placed beneath, and revolving by a wheel and pinion from the water-wheel; a fly-wheel is fixed upon the axis of the crank to equalize the movement, and the pinion is so proportioned, that the crank will make three or four turns to one of the water-wheel. The timber is fastened upon a carriage, which is an horizontal frame, sliding on the floor of the mill; and being sufficiently narrow to pass through the inside of the vertical or moving saw-frame, it will carry the tree through, and subject it to the action of the saw: the carriage is provided with a rack, which is engaged by the teeth of a pinion, and this gives the means of advancing the carriage when the pinion is turned, which is done by means of a large ratchet-wheel, with a click moved by levers, connected with the saw-frame. In this manner, when the saw-frame rises, the click slips over a certain number of teeth of the ratchet-wheel, but when it descends to

make the cut, the click turns the ratchet-wheel round, and advances the wood forwards just as much as the saw will cut into it during its descent. The trees are generally dragged up an inclined plane, through a door at one end of the mill, and being placed upon the carriage, they go through the mill, and are divided by the saw into two or more pieces, which are carried forwards, and go out at a door on the opposite side of the mill, where a boat receives them. Sometimes the saw-frame is fitted up with several saws stretched parallel to each other, and at such distances, that they will divide the whole tree into several boards of any required thickness at one operation.

A great improvement in sawing-machines has been made by Mr. Brunel, by which they are enabled to cut more timber in a given time, with any given power, and also cut much more correctly, and without winding in the surfaces which the saws divide. A capital mill on this plan has been constructed by Mr. Maudslay for the arsenal at Woolwich; it is driven by a steam-engine, which is a pattern of elegance in its appearance, as much as of perfection in its contrivance; the motion is communicated from this to the cranks of the four saw-frames, by leather belts, which are here very judiciously applied in lieu of cog-wheels, because these will slip and yield if any thing should get into the movements, but cog-wheels would in a similar case break every thing to pieces. Each crank has an independent fly-wheel to regulate its motion, in addition to the great fly-wheel of the steam-engine. The vertical or moving frames for the saws are made of iron, but the sides are hollow, and filled up with wood, by which means they are very strong, but of no greater weight than necessary. The most ingenious part of the contrivance consists in the means of stretching all the saws in the frame, so that they will be exactly parallel to each other, and all strained to an equal degree of tension. The saws are so fitted in the frame, that they can be removed in a few minutes, and a new set of sharp saws put in. Each saw has a piece of metal rivetted to it at each end, which are formed like hooks. The hook at the lower end of the saw is hooked into a proper recess made in the lower cross-bar of the saw-frame, and the upper hook is engaged with the hook of a shackle or link, which hangs upon the upper cross-bar, and has wedges through it, by means of which it can be drawn tight to strain the saw. As there is nothing to determine the parts of the cross-bars where the hooks of the saws shall hang upon them, they can be set at any required distance asunder; but to retain them, pieces of hard wood are put in between the blades of the saw at the upper and lower ends, and the spaces being thus filled up, they are bound tight by screws, which are tapped into the sides of the saw-frame. As the tension of the different saws would be very uncertain, if it depended merely upon driving the wedges of their shackles by a hammer, the inventor has applied a very ingenious kind of steelyard, to strain each of the saws in its turn. It consists of the following parts: a strong axis is extended across the fixed frame, in which the saw-frame slides, and above the top of this frame; from one side of

this axis a lever proceeds, which has a weight fixed at the end, and from the opposite side of the axis proceed two short levers, which are connected by links with a strong cross-bar, situated just over the upper cross-bar of the saw-frame, when it is at its greatest point of elevation. This steelyard cross-bar has a link or shackle upon it, which can be united by a key with any one of the shackles upon the upper cross-bar of the saw-frame, which shackles are, as before-mentioned, united by their hooks with the upper end of their respective saws; by this means the lever, with its weight, becomes a steelyard to draw up any one of the saws with a determinate force, and it can be applied successively to all the different saws. In using this apparatus, the band or strap of the crank-shaft is cast off, to stop the motion of the saw-frame; the crank is turned round, to elevate the frame to the highest point; two wedges are then put in between the top of the saw-frame and a fixed part of the stationary frame, and this holds the saw-frame fast whilst the steelyard is applied, otherwise it would tend to draw up the frame, and strain the crank and crank-rod. The sharp saws are now put into the saw-frame, by hooking them upon the lower cross-bar thereof, and uniting the upper hooks to the shackles on the upper cross-bar: the pieces of wood are next put between the saws, according to the gauge of the wood which is intended to be sawn, and bound fast by the screws, as before-mentioned. The loaded end of the steelyard is now lifted up by a rope passing over a pulley, and the link upon the cross-bar of the steelyard is united with the shackle of one of the saws by means of its keys; then suffering the steelyard to descend, it stretches the saw: the wedge of the shackle for the saw is thrust in by the hand as far as it will go, and thus retains the saw at the tension to which the steelyard had strained it. The shackle of the steelyard is then disengaged from this saw and removed to the next, and thus, in turn, all the saws are equally strained, a circumstance which is of great importance, because any saw which is more slack than another will be liable to bend and cut crooked, when the grain of the wood tends to divert it from its true direction.

The carriages of this mill are very admirably contrived to hold the trees firmly, and to fix them in a little time: they are advanced, as the saws cut, by a rack and pinion, with a ratchet-wheel; and the click of the ratchet is moved by means of an excentric wheel, or cam, upon the axis of the crank. There is also a contrivance, by which the saw-frame is allowed to retreat a small quantity in its ascent, so that the teeth of the saw will be quite clear from the wood, when they return, that is, when they ascend, and do not cut. Mr. Brunel has directed the execution of several other saw-mills upon the same principle, particularly a very large one in the dock-yard at Chatham.

Circular Sawing-Machines.—These act by a circular steel plate, having teeth, like those of a pit-saw, cut all round its circumference. This saw is fixed upon an axis, and made to revolve by bands or straps with great rapidity. The wood being presented to it, is cut by a continuous motion; and as this admits of a far greater velocity than can be given to any reciprocating machine, the circular saw cuts a surprising quantity of wood, not less from this circumstance than because it is always in action; whereas the reciprocating saw only cuts in one direction, and all the time occupied in the return is lost. Attempts have been made to make reciprocating saw-frames cut double, by having the different saws reversed, that is, some so placed that they shall cut in ascending, and the others in descending; but this did not succeed, because the saws which do not cut will not allow the others to advance into the wood, at least without great friction upon the back of the returning saws.

The circular saw is usually fixed in a horizontal table, or bench, which has a cleft, through which the saw comes up; the spindle being situated under the bench, and across the direction of its length. A segment or portion of the saw is, therefore, left projecting above the bench; and the piece of wood being laid flat thereupon, it is advanced forwards to the saw, and cut with the greatest facility, and is certain to be cut square; but if the sections are required to be at any other angle or bevel, the bench is inclined to suit it. A long parallel ruler is fixed down upon the bench, and this is capable of being brought nearer or farther from the saw, and thus forms a guide, against which the piece of wood is held; by this the saw cuts always to the same width; but the width can be varied at pleasure.

The time of the introduction of this valuable machine is not well ascertained. Circular saws, for cutting the teeth of watch and clock wheels, have been in use since the time of Dr. Hook; but we do not know who first applied the same to sawing wood in the large way. Mr. Taylor of Southampton used them in his manufactory many years ago; but, we believe, they were most completely introduced by Mr. George Smart, and have since become very general for all kinds of purposes. (See the articles *CANTEEN*, *COMB-CUTTING*, and *MACHINERY, Block*, where descriptions of machines acting with circular saws will be found.) It only remains here to mention an improvement in the mode of mounting them, by Mr. Maudslay. The first saws, as the most simple method, were made with sharp conical points at each end of the spindle, and these were received into conical holes at the ends of screws, fitted through the fold frame of the machine; or, otherwise, the points were made upon the ends of the fixed screws, and the holes in the ends of the spindle. In either case, the parts were made of hardened steel, and the most accurate and convenient circular motion was thus obtained. But if this method is used on a large scale, and with a great velocity, the oil cannot be kept in the sockets, and the friction will then cause the points of contact to heat: by heating, they expand, and thus increase the friction and the pressure, so that the heat is rapidly increased, till the metal becomes soft, and will twist off the points. The reason of the escape of the oil is, that the centrifugal force induces the oil to mount up the cone, and thus escape from the point, where it is chiefly wanted. The saw-spindles made by Mr. Maudslay have double conical sockets, and the oil is introduced by a small hole into the smallest part of the double cones, where they join; by this means, the centrifugal force draws the oil into the fitting, instead of throwing it out, as in the other instance.

An ingenious circular saw was presented to the Society of Arts, by John Trotter, esq., in 1805, and the Society complimented the inventor with their gold medal. It is called a curvilinear saw, being made concave, that is, like a circular dish or bowl, instead of a flat circular plate. If this is a segment of a sphere, the saw will cut segments of circles, instead of straight lines. This is very useful for fellies of wheels, &c.; but by varying the curve of the saw, any required curve of a moderate bend may be cut.

Other circular saws have been made like the trepan used by surgeons; the size, of course, being determined by the size required to be cut. See *MACHINERY, Block*.

A patent has been obtained for a circular saw, or rather a saw with a continuous motion, which consists of an endless steel band or blade, cut with teeth, and extended over two wheels placed at a distance asunder, just like the endless straps which are used to communicate motion from one wheel to another. The wood is applied to that part of

the blade which is extended between the two wheels. We but we fear there would be many difficulties in making such
have not been informed if it is found to succeed in practice; endless belts of steel.

Screw

SCREW, or SCRUB, *Cochlea*, in *Mechanics*, one of the six mechanical powers; chiefly used in pressing or squeezing bodies close, though sometimes also in raising weights. See *MECHANICAL Powers*.

The screw is a right cylinder, as A B (*Plate XXXVIII. Mechanics, fig. 1.*) furrowed spiral-wise; it is generated by the equable motion of a right line F G (*fig. 2.*) around the surface of a cylinder; while, at the same time, the point I descends equably from F towards G. Or, it may be conceived to be made by cutting a piece of paper into the form of an inclined plane, or half-wedge, and then coiling it round a cylinder; so that its action depends on the same principles as that of an inclined plane. The force tending to turn the screw round its axis may be considered as applied horizontally to the base of the wedge, and the weight which is to be raised as acting vertically on its inclined surface: the circumference of the cylinder will represent the horizontal length of the wedge; and the distance between the threads, measured in the direction of the axis, will be its height, provided that the threads be single; consequently, the forces required for the equilibrium are to each other, as the height of one spire to the circumference of the screw. But besides these forces, it is necessary that some obstacle be present, which may prevent the body, on which the screw acts, from following it in its motion round its axis; otherwise there can be no equilibrium. If the furrowed surface be convex, the

screw is said to be *male*; it concave, it is *female*.

Where motion is to be generated, the male and female screw are always joined; that is, whenever the screw is to be used as a simple engine, or mechanical power; and when thus fitted together, they are sometimes called a screw and a nut. The nut acts on the screw with the same mechanical power as a single point would do, since it only divides the pressure among the different parts of the spire. When joined with an axis in *peritrochio*, there is no occasion for a female; but in that case it becomes part of a compound engine.

The screw cannot properly be called a simple machine, because it is never used without the application of a lever, or winch, to assist in turning it. Sometimes the spires of a screw are made to act on the teeth of a wheel, when a very slow motion of the wheel, or a very rapid motion of the screw, is required for the purposes of the machine.

SCREW, *Doctrine of the*. 1. If, as the compass, described by the power in one turn of the screw, is to the interval or distance between any two immediate threads, or spiral windings, as B I (measured according to the length of the screw), so is the weight or resistance to the power; then the power and the resistance will be equivalent one to the other; and, consequently, the power being increased, so as to counteract the friction of the screw, which is very considerable, will overcome the resistance. For it is evident, that in one turn

of the screw, the weight is so much lifted up, or the resistance so much moved, or the thing to be pressed is squeezed so much closer together, as is the distance between two immediate spirals; and in the same time, the power is so much moved, as is the compass described by the said power in one turn of the screw. Wherefore the velocity of the weight (or whatsoever answers thereto) will be to the velocity of the power, as is the said distance between the spirals to the compass described by the power, in one revolution or turning round of the screw; so that the gaining in power is here recompensed by the loss in time.

2. As the distance between two threads, B I, is less; the power required to overcome the said resistance is less; therefore the finer the thread, the easier the motion.

3. If the male screw be turned in the female, at rest, a less power will be required to overcome the resistance, as the lever or scytala C D (fig. 3.) is the longer.

4. The distance of the power from the centre of the screw, C D, the distance of the two threads I K, and the power to be applied in D, being given, to determine the resistance it will overcome: or, the resistance being given, to find the power necessary to overcome it.

Find the periphery of a circle described by the radius C D; then to the distance between the two threads, the periphery just found, and the given power; or, to the periphery found, the distance of the two threads I K, and the given resistance, find a fourth proportional. This, in the former case, will be the resistance that will be overcome by the given power; and, in the latter, the power necessary to overcome the resistance.

E. gr. Suppose the distance between the two threads, 3, the distance of the power from the centre of the screw C D, 25, and the power 30 pounds; the periphery of the circle to be described by the power, will be found 157. Therefore, as 3 : 157 :: 30 : 1570, the weight to which the resistance is equal.

5. The resistance to be overcome by a given power being given; to determine the diameter of the screw, the distance of the two threads I K, and the length of the scytala, or handle: the distance of the threads, and the diameter of the screw, may be assumed at pleasure, if the male be to be turned in the female by a handle. Then, as the given power is to the resistance it is to overcome, so is the distance of the threads to a fourth number, which will be the periphery to be described by the handle C D, in a turn of the screw. The semidiameter of this periphery, therefore, being sought, we have the length of the handle C D. But if the female screw be to be turned about the male, without any handle, then the periphery and semidiameter found will be very nearly those of the screw required.

E. gr. Suppose the weight 6000, the power 100, and the distance of the threads 2 lines; for the periphery to be passed over by the power, say 100 : 6000 :: 2 : 120; the semidiameter of which periphery being $\frac{1}{2}$ of 120 = 40 lines, will be the length of the handle, if any be used; otherwise the side of the female screw must be 40 lines. Mr. Hunter has described a new method of applying the screw with advantage in particular cases. Phil. Trans. vol. lxxi. part i. p. 58, &c.

A cylindrical screw is bored, and made at the same time a tubular screw, with a little difference in the distances of the threads, so that when it is turned within a fixed nut, it rises or sinks a little more or less than the internal screw, which perforates it, would rise or sink by the action of its own threads; and a weight attached to this internal screw ascends, in each revolution, only through a space equal to the difference of the height of the two coils. Here the

machine is analogous to a very thin wedge, of which the thickness is only equal to the difference of the distances of the threads, and which of course acts with a great mechanical advantage. It might, in some cases, be more convenient to make two cylindrical screws of different kinds, at different parts of the same axis, rather than to perforate it. The friction of such machines is, however, a great impediment to their operation.

SCREW, Endless. If a screw be so fitted as to turn a dented wheel D F (fig. 4.) it is called an *endless*, or *perpetual screw*, because it may be turned for ever, without coming at an end. From the scheme, it is evident enough, that while the screw turns once round, the wheel only advances the distance of one tooth.

SCREW, Doctrine of the Endless. 1. If the power applied to the lever, or handle of an endless screw A B, be to the weight, in a ratio compounded of the periphery of the axis of the wheel E H, to the periphery described by the power in turning the handle, and of the revolutions of the wheel D F, to the revolutions of the screw C B, the power will be equivalent to the weight.

Hence, 1. As the motion of the wheel is exceedingly slow, a small power may raise a vast weight, by means of an endless screw; for this reason, the great use of the endless screw is, either where a great weight is to be raised through a little space; or, where a very slow gentle motion is required. On which account it is very useful in clocks and watches.

2. The number of teeth, the distance of the power from the centre of the screw A B, the radius of the axis H E, and the power, being given; to find the weight it will raise.

Multiply the distance of the power from the centre of the screw A B, into the number of teeth: the product is the space of the power passed through, in the time the weight passes through a space equal to the periphery of the axis. Find a fourth proportional to the radius of the axis, the space of the power now found, and the power. This will be the weight which the power is able to sustain. Thus, if A B = 3, the radius of the axis H E = 1; the power 100 pounds, number of teeth of the wheel D F 48; the weight will be found 14,400; whence it appears, that the endless screw exceeds all others in increasing the force of a power.

A machine for shewing the power of the screw, may be contrived in the following manner. Let the wheel C (fig. 5.) have a screw *a b* on its axis, working in the teeth of the wheel D, which we may suppose to be forty-eight in number. It is plain, that for every revolution of the wheel C, and screw *a b*, by the winch A, the wheel D will be moved one tooth by the screw; and, therefore, in forty-eight revolutions of the winch, the wheel D will be once turned round. Then, if the circumference of a circle, described by the handle of the winch, be equal to the circumference of a groove *e* round the wheel D, the velocity of the handle will be forty-eight times as great as the velocity of any given point in the groove. Consequently, if a line G goes round the groove *e*, and has a weight of forty-eight pounds hung to it below the pedestal E F, a power equal to one pound at the handle will balance and support the weight. To prove this by experiment, let the circumferences of the grooves of the wheels C and D be equal to one another; and then, if a weight H of one pound be suspended by a line going round the groove of the wheel C, it will balance a weight of forty-eight pounds hanging by the line G; and a small addition to the weight H will cause it to descend, and so raise up the other weight. If the line G, instead of going round the

groove *e* of the wheel *D*, goes round its axle *I*, the power of the machine will be as much increased, as the circumference of the groove *e* exceeds the circumference of the axle; and if we suppose it to be six times, then one pound at *H* will balance six times 48, or 288 pounds hung to the line on the axle; and hence the power or advantage of this machine will be as 288 to 1; *i. e.* a man, who by his natural strength could lift a hundred weight, will be able to raise 288 hundred, or 14 $\frac{1}{2}$ ton weight by this engine. Ferguson's Mech. edit. 4to. p. 44.

Screw, *Archimedes's*, or the *spiral pump*, or as it is called in Germany, the *water snail*, is a machine for the raising of water, first invented by Archimedes.

Its structure and use will be understood by the following description of it. *A B C D* (Plate XIV. *Hydraulics*, fig. 11.) is a wheel, which is turned round, according to the order of the letters, by the fall of water *E F*, which need not be more than three feet. The axle *G* of the wheel is elevated so as to make an angle of about 44°, or between 45° and 60°, with the horizon; and on the top of that axle is a wheel *H*, which turns such another wheel *I* of the same number of teeth; the axle *K* of this last wheel being parallel to the axle *G* of the two former wheels. The axle *G* is cut into a double-threaded screw (as in fig. 12.), exactly resembling the screw on the axis of the fly of a common jack, which must be what is called a right-handed screw, like the wood screws, if the first wheel turns in the direction *A B C D*; but it must be a left-handed screw, if the stream turns the wheel the contrary way; and the screw on the axle *G* must be cut in a contrary way to that on the axle *K*, because these axles turn in contrary directions. These screws must be covered close over with boards, like those of a cylindrical cask; and then they will be spiral tubes. Or, they may be made of tubes of stiff leather, and wrapt round the axles in shallow grooves cut therein, as in fig. 13. The lower end of the axle *G* turns constantly in the stream that turns the wheel, and the lower ends of the spiral tubes are open into the water. So that, as the wheel and axle are turned round, the water rises in the spiral tubes, and runs out at *L* through the holes *M, N*, as they come about below the axle. These holes, of which there may be any number, as four or six, are in a broad close ring on the top of the axle, into which ring the water is delivered from the upper open ends of the screw tubes, and falls into the open box *N*. The lower end of the axle *K* turns on a gudgeon, in the water in *N*; and the spiral tubes in that axle take up the water from *N*, and deliver it into another such box under the top of *K*; on which there may be such another wheel as *I*, to turn a third axle by such a wheel upon it. And in this manner water may be raised to any given height, where there is a stream sufficient for that purpose to act on the broad float-boards of the first wheel. Ferguson's Mechanics, Supplement, p. 22.

An instrument of a similar nature is called by the Germans a water screw; it consists of a cylinder with its spiral projections detached from the external cylinder or coating, within which it revolves. This machine might not improperly be considered as a pump, but its operation is precisely similar to that of the screw of Archimedes. It is evident that some loss must here be occasioned by the want of perfect contact between the screw and its cover; in general, at least one-third of the water runs back, and the machine cannot be placed at a greater elevation than 30; it is also very easily clogged by accidental impurities of the water; yet it has been found to raise more water than the screw of Archimedes, when the lower ends of both are immersed to a considerable depth; so that if the height of the surface of the

water to be raised were liable to any great variations, the water screw might be preferable to the screw of Archimedes. Plate XIV. *Hydraulics*, fig. 14.

When a spiral pipe, consisting of many convolutions, arranged either in a single plane, or in a cylindrical or conical surface, and revolving round a horizontal axis, is connected at one end by a water-tight joint with an ascending pipe, while the other end receives during each revolution nearly equal quantities of air and water, the machine is called a spiral pump. It was invented about 1746, by Andrew Wirtz, a pewterer at Zurich, and is said to have been used with great success at Florence and in Russia: it has also been employed in this country by Lord Stanhope; and I have made trial of it (says Dr. Young) for raising water to a height of forty feet. The end of the pipe is furnished with a spoon, containing as much water as will fill half a coil, which enters the pipe a little before the spoon has arrived at its highest situation, the other half remaining full of air, which communicates the pressure of the column of water to the preceding portion, and in this manner the effect of nearly all the water in the wheel is united, and becomes equivalent to that of the column of water, or of water mixed with air, in the ascending pipe. The air nearest the joint is compressed into a space much smaller than that which it occupied at its entrance, so that where the height is considerable, it becomes advisable to admit a larger portion of air than would naturally fill half the coil, and thus lessens the quantity of water raised, but it lessens also the force required to turn the machine. The joint ought to be conical, in order that it may be tightened when it becomes loose, and the pressure ought to be removed from it as much as possible. The loss of power, supposing the machine well constructed, arises only from the friction of the water on the pipe, and the friction of the wheel on its axis; and where a large quantity of water is to be raised to a moderate height, both of these resistances may be rendered inconsiderable. But when the height is very great, the length of the spiral must be much increased, so that the weight of the pipe becomes extremely cumbersome, and causes a great friction on the axis, as well as a strain on the machinery: thus, for a height of 40 feet, Dr. Young found that the wheel required above 100 feet of a pipe which was three quarters of an inch in diameter; and more than one half of the pipe being always full of water, we have to overcome the friction of about 80 feet of such a pipe, which will require 24 times as much excess of pressure to produce a given velocity, as if there were no friction. The centrifugal force of the water in the wheel would also materially impede its ascent if the velocity were considerable, since it would be always possible to turn it so rapidly as to throw the whole water back into the spoon. The machine which Dr. Young had erected being out of repair, he thought it more eligible to substitute for it a common forcing pump, than to attempt to make any further improvement in it, under circumstances so unfavourable. But if the wheel with its pipes were entirely made of wood, it might in many cases succeed better: or the pipes might be made of tinned copper, or even of earthenware, which might be cheaper and lighter than lead. See fig. 15.

The centrifugal force, which is an impediment to the operation of Wirtz's machines, has sometimes been employed together with the pressure of the atmosphere, as an immediate agent in raising water, by means of the rotatory pump. This machine consists of a vertical pipe, caused to revolve round its axis, and connected above with a horizontal pipe, which is open at one or at both ends, the whole being furnished with proper valves to prevent the escape of the water when the machine is at rest. As soon as the rota-

tion becomes sufficiently rapid, the centrifugal force of the water in the horizontal pipe causes it to be discharged at the end, its place being supplied by means of the pressure of the atmosphere on the reservoir below, which forces the water to ascend through the vertical pipe. It has also been proposed to turn a machine of this kind by the counter-pressure of another portion of water, in the manner of Parent's mill, where there is fall enough to carry it off. This machine may be so arranged, that, according to theory, little of the force applied may be lost; but it has failed of producing in practice a very advantageous effect. Young's Phil. vol. i. See *CENTRIFUGAL Machine*, and *WHEEL*.

SCREW, Bed or Barrel, a powerful machine for lifting heavy bodies; and, when placed against the gripe of a ship

to be launched, for starting her. It consists of two large *poppets*, or male screws, having holes in their heads to admit levers to turn therewith, a *bed* formed of a large oblong piece of elm, with female screws near each end to admit the poppets, and a sole of elm plank for the heels of the poppets to work on. When used for launching of ships, the surface of the sole is inclined so as to stand square to the stem or gripe.

Hand-screws, or *jacks*, double or single, are used by hand to lift weighty bodies. It consists of an elm box, containing cogged iron wheels, of increasing powers. The outer one, which moves the others, is put in motion by a winch or handle on the outside. They are called single or double, according to their increasing force.

Serge

SÉRGE, in *Commerce*, a woollen quilted stuff, manufactured on a loom with four treddles, after the manner of ranteens, and other stuffs that have the whale.

The goodness of serges is known by the quilting, as that of cloths by the spinning.

Of serges there are various kinds, denominated either from the different qualities of them, or from the places where they are wrought. The most considerable is the London serge, now highly valued abroad, particularly in France, where a manufacture has been carried on with good success, under the title of *serge façon de Londres*.

SERGE, *Manufacture of London*. For wool, the longest is chosen for the warp, and the shortest for the woof. Before either kind is used, it is first scoured, by putting it in a copper of liquor, somewhat more than lukewarm, composed of three parts of fair water and one of urine. After having stood long enough therein for the liquor to dissolve, and take off the grease, &c. it is stirred briskly about with a wooden peel; taken out of the liquor, drained, and washed in a running water, dried in the shade, beaten with sticks on a wooden rack, to drive out the coarser dirt and filth, and then picked clean with the hands. Thus far prepared, it is greased with oil of olives, and the longest part, destined for the warp, is combed with large combs, heated in a little furnace for the purpose. To clear off the oil again, the wool is put in a liquor composed of hot water, with soap melted in it: whence being taken out, wrung, and dried, it is spun on the wheel.

As to the shorter wool, intended for the woof, it is only carded on the knee with small cards, and then spun on the wheel, without being scoured of its oil. Note, the thread for the warp is always to be spun much finer, and better twisted than that of the woof.

The wool both for the warp and the woof being spun, and the thread divided into skains, that of the woof is put on spools (unless it have been spun upon them) fit for the

cavity or eye of the shuttle; and that for the warp is wound on a kind of wooden bobbins to fit it for warping. When warped it is stiffened with a kind of size, of which that made of the shreds of parchment is held the best; and when dry is put on the loom.

When mounted on the loom, the workman raising and falling the threads (which are pulled through a reed), by means of four treddles placed underneath the loom, which he makes to act transversely, equally and alternately, one after another, with his feet, in proportion as the threads are raised and lowered, throws the shuttle across from one side to the other; and each time that the shuttle is thrown, and the thread of the woof is crossed between those of the warp, strikes it with the frame to which the reed is fastened, through whose teeth the threads of the warp pass; and this stroke he repeats twice or thrice, or even more, till he judges the crossing of the serge sufficiently close: thus he proceeds till the warp is all filled with woof.

The serge now taken off the loom is carried to the fuller, who fulls, or scours it in the trough of his mill, with a kind of fat earth, called fullers-earth, first purged of all stones and filth. After three or four hours scouring, the fullers-earth is washed out in fair water, brought by little and little into the trough, out of which it is taken when all the earth is cleared; then, with a kind of iron pincers, or plyers, they pull off all the knots, ends, straws, &c. flicking out on the surface on either side; and then returning it to the fulling trough, where it is worked with water somewhat more than lukewarm, with soap dissolved therein for near two hours: it is then washed out till such time as the water becomes quite clear, and there be no signs of soap left; then it is taken out of the trough, the knots, &c. again pulled off, and then put on the tenter to dry, taking care as fast as it dries to stretch it out both in length and breadth till it be brought to its just dimensions. When well dried, it is taken off the tenter, and dyed, shorn, and pressed.

Shaft

SHAFT, in *Building*. The *shaft* of a column is the body of it; thus called from its straightness; but by architects more frequently the *foot*. See the dimensions under **COLUMN**.

SHAFT is also used for the spire of a church-steeple; and for the shank or tunnel of a chimney.

SHAFT, or *Tunnel-Pit*, is the well through which the stuff, excavated from a tunnel, is drawn up to the surface.

SHAFT of a *Mine*, is the hollow entrance or passage into a mine, sunk or dug to come at the ore.

In the tin-mines, after this is sunk about a fathom, they leave a little, long, square place, which is called a *shamble*.

Shafts are sunk some ten, some twenty fathoms deep into the earth, more or less. Of these shafts, there is the landing or working-shaft, where they bring up the work or ore to the surface; but if it be worked by a horse engine or whim, it is called a whim-shaft; and where the water is drawn out of the mine, it is indifferently named an engine-shaft, or the rod-shaft. See **MINE** and **QUARRY**.

SHAFT, in *Agriculture*, a name provincially applied to a handle of a tool; as a spade, fork, &c.

SHAFTS of *Carts and Waggon*s, the parts or poles between which the thill-horses draw. The manner in which the fore-horses are attached to these shafts, when there are more than the thill-horses in the teams, is a matter of great consequence; as the weight or pressure on them is more or less, according to its nature, and the way in which it is performed. See **THILL-Horses** and **WAGGON**.

SHAFT-Drain, that sort which is effected by carrying a sort of shaft or pit down to the porous stratum below, and which is in use where a superficial descent cannot be had for the collected waters, and an open stratum lies beneath the subsoil, ready to receive it. A communication between them becomes here of high advantage, as the cost and attention of raising the water by machinery may thereby be avoided. In cases of this kind, Mr. Marshall advises the drainer to ascertain the lowest point of the site to be improved; and there, says he, sink a shaft down, and into,

the receiving stratum, and fill it up to within a few feet of the surface, with rough stones, the roots of trees, or other open materials; and, on the top of these, form a filter, with heath and gravel, or other substances, that will prevent earthy matter, or water in a foul state, from entering the shaft: and to this filter lead the collected waters. And that where the water is collected by the means of covered drains, and where the filter also has a covering placed over it, the entire process will be free from external injury; and a work of this kind may remain unimpaired for ages. But even if the waters were collected by open drains, and the filter were suffered to remain in a state of neglect, until the shaft, in process of time, should become defective, the remedy would be easy. Embrace, says he, a dry season to re-open the shaft, and to cleanse it, and the materials with which it may be filled, from their impurities; and thus restore it, at a small expence, to its original state of perfection. It is further stated also, that if the site of improvement be liable to any other surface-water, than what falls on its own area, such water ought to be conducted away from it superficially, by cutting it off at such a height as will gain a sufficient fall. And that where the quantity of water, which descends into it subterraneously, (or would descend, if a free passage were opened for it,) should be found to be too copious to be readily discharged by a shaft-drain, in the manner here proposed, proper efforts should be used to cut off the supply, or as much of it as may be, by a perforated trench or otherwise, at a sufficient height to be able to convey it away superficially; and with a sufficient fall, to prevent its entering the area to be improved; which will thus have only its own superfluous waters to discharge by the shaft. He is desirous to clear the way which leads to this valuable improvement, as he is convinced that there are many instances in which it might be applied with great profit. Many of the low, flat-lying, moory vallies of Norfolk, from whose bases superficial drains would be difficult to make, have for their substructures, it is probable, he says, insatiable depths of sand; and that, in every district of the island, such objects as are proper for this practice may be found.

Sheffield

SHEFFIELD, or *Sheaffield*, in *Geography*, a large and populous market and manufacturing town in the fourth division of the wapentake of Strafford and Tickhill, liberty of Hallamshire, West Riding of Yorkshire, England, is situated at the distance of 36 miles S. from Leeds, and 162 N.N.W. from London. The origin and remote history of this town are totally unknown. In the 13th century it was noted as a staple for articles of iron manufacture. Chaucer, who wrote in the reign of Edward III., mentions the "Sheffield Whittle" in one of his poems. At that period it was likewise distinguished by a strong castle, which stood at the north-east of the town, and is said to have been built during the sovereignty of Henry III. This castle descended from the Lovetofts to the Nevils, lords Furnival, and passed from them to the Talbots, earls of Shrewsbury, and subsequently to the Howards, dukes of Norfolk, in whose family the lordship of the manor is still vested. During the civil wars between Charles I. and his parliament, Sheffield castle sustained a long siege in the cause of royalty, but eventually surrendered upon honourable terms, on the 10th of August, 1644, and was soon afterwards ordered to be demolished, which seems to have been done most effectually, as scarcely a vestige of it can now be discovered.

Though Sheffield, as already said, was considered as a staple for iron manufactures at a very early period, its trade, for several centuries, was comparatively confined and precarious, and consisted almost entirely in the making of sheath-knives, scissiors, sickles, and scythes. About the commencement of the 17th century, an ordinary kind of tobacco-box of iron, and Jews' harps, began to be manufactured here; and in 1625 the master manufacturers were first incorporated by the style of "The Company of Cutlers of Hallamshire." This corporation is governed by a master, elected annually, six searchers, and twenty-four assistants, and is the only body corporate yet existing in Sheffield. It was not, however, till after the year 1750, that this town assumed the rank it now holds in manufacturing opulence. Previously to that period, none of the manufacturers had extended their traffic beyond the limits of Great Britain; but in the same year Mr. Joseph Broadbent opened a direct trade with the continent; and in 1751, the river Don having been rendered navigable to within three miles of the town, that facility was given to exportation, which has since proved so beneficial to its manufacturing interests. Soon afterwards Mr. Thomas Bolsover began to plate brass and copper buttons with silver; and in 1758 the silver plated manufacture was commenced on an extensive scale by Mr. Joseph Hancock, and has subsequently been prosecuted with great advantage by a numerous class

of individuals. The opulence and population of the town increased from that time with great rapidity, and soon gave rise to numerous conveniences and improvements, both useful and ornamental. In 1760, the first stage-coach started from Sheffield for London; and in 1762, the theatre and assembly-room were built by subscription. In 1770, the first bank in Sheffield was opened by Mr. Roebuck; and in 1786, the new market-place was formed, about the same time that Messrs. Proctors erected the first steam-engine grinding-wheel. In 1793, hackney coaches were introduced; and in the same year also was laid the foundation of the General Infirmary. These circumstances are mentioned, because they are calculated to display the progressive benefits resulting from successful industry and ingenuity, the contemplation of which can scarcely fail to excite pleasurable emotions in every breast.

To notice particularly the various articles manufactured at Sheffield of late years, would occupy too considerable a space to admit of the attempt. The two great divisions of them are into cutlery and plated goods, each of which branch out into numerous ramifications. The manufacture of the latter is almost entirely confined to the town, and comprehends a great diversity of articles: such as tea-urns, coffee-pots, tankards, cups, candlesticks, and other pieces of table furniture. The cutlery division embraces the making of edge-tools, combs, cases, buttons, fenders, files, anvils, joiners' tools, lancets, forks, hawks, ink-stands, nails, knives of every description, scissiors, scythes, sickles, awl-blades, bellows, &c. to which we shall only further add the refining of steel. Many of these manufactures are carried on in the country, as well as in the town, especially in the villages and hamlets of Alverthorpe, Bentsgreen, Brightside, Butterthwaite, Carbrooke, Darnall, Dyson-Holmes, Dungworth, Ecclesfield, Greenock, Grimesthorpe, Hallam, Miln-houses, Newfield-Green, Owlerton, Pittsmoor, Stannington, Shiregreen, Upper-Heeley, Wadsley, Woodleats, &c.; all of which are situated within seven miles of Sheffield. Besides the above manufactures, there are in the town and its vicinity several extensive founderies for iron, brass, and white metal.

Sheffield occupies a fine eminence at the confluence of two rivers, the Sheaf, whence the name of the town is derived, and the Don. In former times the houses were entirely built of stone; but for the last century they have been chiefly composed of brick. There are few towns which surpass it in the regularity of its streets, many of them running in a direct line, and displaying a series of uniform and respectable edifices. Sheffield extends about

a mile in length, from north to south, and nearly as much in breadth, from east to west. According to the population census of 1811, it contains 7927 houses, and 35,840 inhabitants, being an increase of 4526 persons since 1801, the date of the preceding report, notwithstanding the retardation its manufacturing prosperity has sustained during that eventful period. According to Gosling's plan of the town, made in 1732, there were 32 streets in Sheffield at that time: in 1771 these were increased by 25 new streets; and in 1792, seventeen additional streets had been made.

Sheffield is not particularly distinguished by the superiority of its public buildings, which are rather calculated for purposes of utility than for show. The principal of them are the Town-hall, built in 1700, Cutlers'-hall, the General Infirmary, the assembly-room, and theatre, and four churches belonging to the establishment. Neither the Town-hall nor Cutlers'-hall deserve attention as architectural productions; but the infirmary and theatre are handsome structures. The former, commenced in 1793, stands on the west side of the town; and in respect of situation, plan, medical aid, and comfortable treatment, may vie with almost any similar institution in Great Britain. The latter, which occupies the same building with the assembly-room, stands in Norfolk-street. The four churches are Trinity church, St. Paul's, St. James's, and a chapel belonging to the duke of Norfolk's hospital. Trinity church, anciently called St. Peter's, is the parish church of Sheffield, and appears to have been erected as early as the reign of Henry I. On the south side of the chancel is the Shrewsbury chapel, which contains four monuments to the memory of the earls of Shrewsbury of the family of Talbot: and on the north side is a monument commemorating judge Jessop of Broom-hall, and his lady. At the entrance to the same division of the church are deposited the remains of William Walker, of Darnal, in this parish, who is said to have been the executioner of Charles I. Besides the above churches, Sheffield contains seven meeting-houses for Protestant dissenters, one for Unitarians, two for Methodists, one for Quakers, and a Roman Catholic chapel.

The duke of Norfolk's hospital, mentioned above, stands on the eastern bank of the Sheaf. It was founded and endowed in 1670, by Henry, earl of Norwich, and received a considerable accession of property by Edward, duke of Norfolk, in 1770. The building consists of two quadrangles, each containing eighteen dwellings, for the accom-

modation of eighteen men, and the same number of women, all of whom receive five shillings a-week, with clothing and coals. Here is also an hospital founded by Mr. Thomas Hollis, a merchant of London, in 1703, for poor cutlers' widows; likewise a free grammar-school, and two charity-schools; one for boys, and another for girls.

The other objects of a public kind which remain to be noticed are, the military barracks, situated at the north-eastern extremity of the town; and the bridges thrown over the Sheaf and the Don. That upon the latter river is called Lady's bridge, from a religious house, which formerly stood near it, and was dedicated to the Virgin Mary. It was built in 1485, but underwent great alterations and improvements in 1762.

Sheffield has two market days, weekly, Tuesday and Saturday; the first for corn, &c. and the second for butchers' meat. There are also fish-markets on Monday and Thursday, and two annual fairs, one on the first Tuesday after Whitsun week, and another on the 28th of November. A new market-place, with extensive and commodious shambles and other conveniences, was formed and finished here Aug. 31, 1786. Sheffield supports a weekly newspaper, called the "*Iris*," which is edited by Mr. James Montgomery, the author of "*The World before the Flood*," and other interesting poems.

The scenery in the vicinity of this town may be characterized as romantic. It is surrounded by lofty hills, commanding fine views over a populous and variegated country. At the distance of about a mile and a half to the eastward, stand the ruins of Sheffield manor-house, the ancient seat of the earls of Shrewsbury, where cardinal Wolsey was seized with the disease which terminated his life about a week afterwards, at the abbey of Leicester. Wharnccliffe park, the seat of the honourable James Archibald Stuart Wortley, situated on the river Don, six miles to the north-west of Sheffield, is equally remarkable for the elegance of its mansion, and the beauty of the surrounding grounds. In the neighbourhood of Sheffield are some alum mines; and at Wickersley, near the town, is a quarry, which supplies the manufacturers with grind-stones for the finer articles of cutlery. Aikin's *Description of the Country round Manchester*, 4to. 1795. *Magna Britannia*, 4to. 1703. *Camden's Britannia*, fol. edit. 1789. *Beauties of England and Wales*, vol. xvi. by John Bigland, 8vo. 1812. *Gentleman's Magazine*, April and September, 1764.

Shoad

SHOAD, in *Mining*, a term for a train of metalline stones mixed with earth, sometimes lying near the surface, sometimes at considerable depths, but always serving to the miners as a proof that the load or vein of the metal is thereabout. The deeper the shoad lies, the nearer is the vein.

SHOAD-Stones, a term used by the miners of Cornwall, and other parts of this kingdom, to express such loose masses of stone, as are usually found about the entrances into mines, sometimes running in a straight course, from the load or vein of ore to the surface of the earth.

These are stones of the common kinds, appearing to have been pieces broken from the strata, or larger masses, but they usually contain mundic or marcasitic matter, and more or less of the ore to be found in the mine. They appear to have been at some time rolled about in water, their corners being broken off, and their surface smoothed and rounded.

The antimony mines in Cornwall are always easily discovered by the shoad-stones, these usually lying up to the surface, or very nearly so; and the matter of the stone being a white spar, or debased crystal, in which the native colour of the ore, which is a shining blueish-black, easily discovers itself in streaks and threads.

Shoad-stones are of so many kinds, and of such various appearances, that it is not easy to describe or know them:

but the miners, to whom they are of greatest use in the tracing, or searching after new mines, distinguish them from other stones by their weight; for if very ponderous, though they look ever so much like common stones, there is great reason to suspect that they contain some metal. Another mark of them is their being spongy and porous; this is a sign of especial use in the tin countries, for the tin shoad-stones are often so porous and spongy, that they resemble large bodies thoroughly calcined. There are many other appearances of tin shoads, the very hardest and firmest stones often containing this metal.

When the miners, in tracing a shoad up hill, meet with such odd stones and earths, that they know not well what to make of them, they have recourse to vanning, that is, they calcine and powder the stone, clay, or whatever else is supposed to contain the metal; and then washing it in an instrument, prepared for that purpose, and called a *vanning shovel*, they find the earthy matter washed away, and of the remainder, the stony, or gravelly matter lies behind, and the metalline matter at the point of the shovel. If the person who performs this operation has any judgment, he easily discovers not only what the metal is that is contained in the shoad, but also will make a very probable guess at what quantity the mine is likely to yield of it in proportion to the ore. Phil. Transf. N^o 69. Price's Mineralogia, p. 124, &c.

Shoe

SHOE, in *Geography*, a small island in the Pacific ocean, near the coast of Waygoo. S. lat. $5^{\circ} 1'$. E. long. $130^{\circ} 53'$.

SHOE *Indians*, Indians of North America, in an island of lake Missouri. N. lat. $48^{\circ} 15'$. E. long. $105^{\circ} 45'$.

SHOE, a covering for the foot, usually of leather.

Its structure, though the object of a particular art, is too popular to need explaining.

Its history is more obscure. Bend. Baudoin, a shoe-maker by profession, has a learned treatise of the ancient shoe, "*De Solea Veterum*," where the origin, matter, form, &c. thereof, are particularly inquired into.

Baudoin maintains, that God, in giving Adam skins of beasts to clothe him, did not leave him to go bare-footed, but gave him shoes of the same matter; that, after raw skins, men came to make their shoes of rushes, broom, paper, flax, silk, wood, iron, silver, and gold; so different has their matter been. Nor was their form more stable, with regard either to the shape, colour, or ornaments; they have been square, high, low, long, and quite even, cut, carved, &c. Pliny, lib. vii. c. 56, tells us, that one Tychius, of Bæotia, was the first who used shoes.

M. Nilant, in his remarks on Baudoin, observes, that he quotes Xenophon wrongly, to shew that even in his time they still wore shoes of raw skins.

Xenophon relates, that the ten thousand Greeks, who had followed the young Cyrus, wanting shoes in their retreat, were forced to cover their feet with raw skins, which occasioned them great inconveniences.

Nilant will not even allow, that the shoes of the country people, called *carbatina*, and *peroneæ*, were of crude skin, without any preparation.

The patricians, among the Romans, wore an ivory crescent on their shoes: Helioabalus had his shoes covered over with a very white linen, in conformity to the priests of the sun, for whom he professed a very high veneration; this kind of shoe was called *adæ*, *udo*, or *odo*. Cængula wore shoes enriched with precious stones. The Indians, like the Egyptians, wore shoes made of the bark of the papyrus. The Turks always put off their shoes, and leave them at the doors of the mosques.

SHOES made by rivetting instead of sewing. A patent

was taken out for this invention in 1809, by Mr. David Mead Randolph, an American. In his specification, he describes that the rivetting which he proposes to substitute for sewing, is only applicable to the soles and heels of boots or shoes, all the other parts being made in the usual manner. The *last* which is used for this method is the only implement which demands a particular description. It is first made in wood, of the same figure as the common last, and adjusted in the usual manner to the size and shape of the shoe which is intended to be made or put together upon it. The lower part or sole of the last is then covered with a plate of iron or steel, about the same thickness as a stout sole leather: this plate, being formed to the exact shape which is desired, is fastened down upon the wood by screws or rivets. The iron plate has three circular holes made through it, one at the toe, another about half way between the toe and the heel, and a third at the heel: the holes are about an inch in diameter, and being filled up with wooden plugs, and cut down even with the surface of the iron, they will admit the points of temporary nails to be driven through the leather sole to penetrate into the wood, and fix the sole upon the last whilst the work goes on.

The making of the shoe is conducted in the usual manner, until it is ready for putting on the last. To do this, the inner sole is put upon the iron sole of the last; then the upper-leathers are put upon the opposite part, and the edges of the leather are turned down over the edges of the inner sole: the outer sole is then applied over the turning-down, and fastened in a temporary manner upon the last, by driving one or two nails, through both soles, into the wooden plugs before mentioned, which fill up the holes in the iron face of the last. Now, to unite the two soles to the upper-leathers, holes are pierced all round the edges of the sole, and small nails are driven in, which are of sufficient length to penetrate through the sole and the turning-in of the upper-leathers, and also through the inner sole, so as to reach the metal face of the last, and being forcibly driven, their points will be turned by the iron, so as to clench within, or rivet through the leather, and serve instead of the sewing or stitching commonly employed to unite the sole to the upper-leathers.

SHOES, Machines for making. These are the invention of Mr. Brunel, of whose mechanical genius we have had frequent occasion to speak in this work. He has lately established at Battersea an extensive manufactory of shoes, chiefly intended to supply the army, where all the operations are performed by the aid of machines, which act with such facility, that they can be managed by the invalid soldiers of Chelsea Hospital, who are the only workmen employed, and most of them disabled by wounds, or the loss of their legs, from any other employment.

The shoes made by these machines are different from the common shoes, in the circumstance of the sole being united to the upper-leathers by a number of small rivets instead of sewing, in the same manner as those we have mentioned in the preceding article. To facilitate the description we intend to give of the machines, we shall first describe the structure of one of these shoes. Its upper-leathers are the same as any other shoes, and consist of three pieces; *viz.* the vamp, or part which covers the upper part of the foot, and the two quarters which surround the heel, and are sewed together behind it; they are also sewed to the vamp at about the middle of the length of the shoe. The sole part of the shoe is composed of the real or lower sole, with its welt, the heel, and the inner or upper sole.

The lower sole has an additional border, which is called the runner, or welt, fixed upon its upper side, all round the edge, by a row of rivets, so that it makes a double thickness to the sole towards the edge; but this additional piece is only of small width from the outside of the sole inwards, and gradually diminishes away in thickness to nothing, as it recedes from the edge of the sole, so that the middle part of the sole is only of the same thickness as the single leather. The upper-leathers are made sufficiently large to turn in, all round, beneath the foot, under the edge of the inner sole, for about three-quarters of an inch wide, and the outer sole, reinforced by the welt, is applied beneath, so that the turning-in is included between the two soles; that is, it is included between the edge of the inner sole and the welt, or extra thickness which surrounds the lower sole. To hold the shoe together, a row of rivets is put through the sole, all round the edge, and they are of sufficient length to pass through all the four thicknesses, *viz.* the lower sole, the welt, the upper-leathers, (where they are turned in,) and also through the inner sole; and these rivets being made fast, unite the parts of the shoe together in a much firmer manner than sewing. The rivets have no heads, but are made tapering, and the largest ends are on the outside of the sole, which prevents them from drawing through; and at the same time, the strength of the rivetting will not be materially impaired by the gradual wearing away of the sole leather.

These rivets prevent the wear in a very great degree, and for this reason there is a greater number of rivets put into the sole than merely those which hold the shoe together. The different nails are, first, the *short nails*, or rivets, which only penetrate through the single thickness of the lower sole; these are arranged in parallel rows across the tread of the foot, that is, about two-thirds of the length from the heel; there is likewise a double row of short nails, which is carried round parallel to the outline of the toe, at about three-quarters of an inch from the edge, and extends as far as the middle of the foot. Next, the *tacking nails*, which are of a sufficient length to reach through both the sole and the welt, and thus fix the two together: of these, there is a row all round the edge of the foot, nearer to the edge than the row of short nails before mentioned. Lastly, the *long nails*, which, as before described, fasten the shoe together: these form also a complete row round the edge of the

whole shoe, and nearer to the edge than any of the preceding rows. The heel is also fastened on by a row of long nails round its circumference. The heads or thick ends of all these nails appear on the lower surface of the sole, and all contribute to preserve the leather from wearing. We shall now proceed to a description of the ingenious instruments and machines used in this manufactory, beginning with those for

Cutting out the Leather.—This is performed by stamps, each of which is an iron frame or ring, bent to the size and figure of the sole, or other part to be cut out by it: one edge of the frame is edged with steel, and ground sharp, so that it will cut the leather: the sharp edge of this frame being placed upon the skin, and struck with a mallet, will cut out a piece from the skin, which is exactly of the same size as the interior opening of the frame. The leather for the soles is first softened, by soaking it in water; the skin is then spread out on a block or table of lead about two feet long and eighteen inches wide, and the stamp or knife for the soles is placed upon the skin in the most advantageous position to cut out the piece; then two or three blows upon the top of the knife with a beetle or large wooden mallet, forces its edge through the leather, and cuts out the piece, which remains in the opening of the knife, but being taken out another is cut in a similar manner.

A knife of this kind is provided for all the pieces which are used to form the shoe, and they are called after the names of the respective pieces, which are as follow: 1. The sole, which is not cut out the full size for the sole of the shoe, but wants a piece at the heel. 2. The sole-piece is a semi-circle, to be joined to the sole to make up the heel. 3. The heel: these two last pieces are cut out of the small pieces, or scraps of leather. 4. The runner, or welt, which is applied upon the sole, all round the edge, to make the extra thickness where the upper-leather is to be joined to the sole. All these parts are cut out from the strong hides. 5. The inner sole. The upper-leathers are, 6, the vamp, or part which covers the toes and upper part of the foot; 7 and 8, the right and left quarters, which surround the heel, and are sewed to the vamp, being also sewed together behind the heel.

All these parts, except the welts, are cut out by knives of the above description, there being a set of knives for every different-sized shoe which is made in the manufactory. For cutting out the inner soles, the knife is fixed horizontally, with its edge upwards, beneath a heavy cast-iron lever, which moves on a centre pin, supported in the same framing which sustains the knife. The lever has a plate of lead attached to it near the centre, so that when it is brought down horizontally the lead will descend upon the knife, the edge of which being imprinted into the lead, will cut through the leather which is previously spread upon the knife. To use this cutting-out machine, the sole is first cut out roughly from the skin by a common cutting-knife round a wooden pattern, and the lever being lifted up nearly to a vertical position, the rough sole is laid fairly upon the edge of the knife; then, by letting fall the lever, its weight, and the leverage upon the plate of lead, causes a sufficient pressure upon the leather to force it upon the edge of the knife, and cut it to the exact shape required. The lever is guided in its descent, to ensure that its lead shall fall precisely upon the knife.

Immediately after the soles are cut out, they are stamped on the grain-side of the leather with a number which denotes the size of the shoe to which they belong. The stamp is engraved on the face of a small hammer, so that one blow makes the desired mark. The heels and other parts are also

marked, that the workman may make no mistakes in putting the shoes together.

The leather for the welts is cut into strips of about an inch wide: for this purpose, the piece is spread on a flat table about two feet square, the surface of which is covered with small iron rulers the width of the intended strips, and screwed down upon the wooden table, leaving between them sufficient spaces to admit the point of a knife. Several small pins project up from these iron rulers to penetrate the leather and hold it fast. To confine the leather down whilst it is cut, a frame of iron is fixed to the table by hinges at one end, so as to fold down horizontally upon the leather, and the frame is covered all over with similar rulers, the intervals between them corresponding exactly with those between the rulers on the table. The cutting is performed by a hooked knife, fixed into a long handle. The workman holds down the frame upon the leather, and introducing the hooked point of the knife between the bars, draws it towards him; this cuts through the leather, and he repeats it at every interval between the rulers, and thus divides the whole leather into slips of the same breadth as the rulers.

To prepare these slips for use, each one is split lengthways into two other slips, by an oblique cut along the middle of it; thus producing two slips, which have bevelled or feathered edges, similar to a ruler for drawing. The splitting of the strips is performed by a very complete machine, consisting of a pair of brass rollers, one of which is turned by a winch, and the other receives its motion from it by means of a pair of equal cog-wheels, one wheel being fixed upon the ends of each of the rollers. The rollers are mounted one above the other in an iron frame, in a similar manner to those used for laminating: the lower one has a groove formed round it, which is of a proper size to receive the strip of leather before it is divided, and the pressure of the upper roller compresses it into the groove. A guide, consisting of an iron stem, with a square hole through it, is fixed up before or in front of the rollers, to conduct the leather into the groove; and on the opposite side, or behind the rollers, is a stem, or standard, which receives a cylindrical steel pin, and holds it fast in an horizontal position, in the direction in which the strip of leather will move when it comes through the rollers. The end of this steel pin is flattened and ground to a fine sharp edge, like that of a chisel, and presenting itself to the end of the strip of leather as it is passed through the rollers, will evidently divide the strip longitudinally into two pieces, when the leather is forced forwards against the edge of the cutter by the motion of the rollers. This edge is placed obliquely to the axis of the rollers (or to the surface of the leather which passes between them), and therefore will divide it by an oblique cut, so as to produce two narrow feather-edged pieces from each strip. The pressure of the rollers upon the leather tends to consolidate its texture, and supply the place of hammering.

Preparation of the Soles.—The leather is hardened by passing it between rollers, to produce the same effect as hammering does in the ordinary method of shoe-making. The rollers used for this purpose are made of brass, about five inches diameter, and as much in length; they are mounted in the usual kind of frame, except that instead of screws to hold down the upper roller, and regulate its distance from the lower one, two plain cylindric pins are inserted into the holes which usually receive the screws, and these pins have a strong lever bearing upon their upper ends, to press the upper roller down upon the lower, by the action of a weight at the extremity of the lever. These pins are only about four inches distant from the centre or fulcrum of the lever, and the weight (of about 100 pounds) is at a distance

of four feet from the centre, it therefore presses down the upper roller upon the lower, with a force of nearly 1200 pounds. The lower roller has a cog-wheel upon the extremity of its spindle, which is moved by a pinion upon the end of an axis turned by a winch; one man turns this winch and another puts the soles between the rollers. Two soles are presented together, being laid one upon the other, with the flesh sides of the leather towards each other, and an iron plate is placed between them, which is made thick in the middle, and diminishes every way to the edges, where it is thin. The grain or hair side of the leather of the two soles is outside, so as to be in contact with the rollers when the soles are presented to the machine which draws them in; and when they have nearly passed through, the man who turns the winch reverses the motion, and rolls them back again, then forwards, and so on for four or five times, in the same manner as the motion for mangling linen. After this operation the leather becomes hard and solid, and much reduced in thickness, particularly at the middle part.

The heels being so small cannot conveniently be rolled; but to produce the same effect they are stamped in a fly-press: for this purpose, a heel-piece is put into a small box or cell of cast-iron, of a proper shape to receive it, and a thick plate, which is fitted to the box, being laid upon it, the whole is put beneath the screw of the press, one blow of which is sufficient to press the iron plate upon the leather, with a force which will render it hard and solid.

The sole is made complete by joining to it the small semicircular piece at the heel; for this purpose, the parts which are to be joined together are cut bevelled, so that they will overlap without increasing the thickness, and then three or four nails are driven through the bevelled parts, to hold them together. To cut the joints bevelled, a simple press is used; the sole is laid flat upon the edge of the bench, and a piece of iron is pressed down upon it by a lever, upon which the workman leans his elbow. The edge of the bench is bevelled, and faced with iron, and this, together with the upper piece of iron, guides the knife, so that it will cut the joint bevelled: the heel-piece is then cut in the same manner, but reversed.

Application of the short Nails.—The leather for the sole is next inlaid with short copper or iron nails, which are put through holes in the leather, in the broad part of the foot, where the greatest wear will take place; and there is also a double row of similar rivets, inlaid round the toe part, at about three-quarters of an inch within the edge of the sole. The holes for these nails are first punched in the leather of the sole by a punching machine, and then a second machine cuts the nails, and inserts them into the holes.

The *punching machine* is moved by the foot of the workman, who is seated before a small semicircular table of cast iron, on which he places the leather. This table is supported by a strong column, rising from the floor to a height of about two feet above the table, which is joined to the column by a projecting bracket, so that the column is on the opposite side to that where the workman is seated. The upper part of the column has two arms, projecting forwards from it towards the workman, and extending over the table; at their extremities they are formed into sockets, to sustain a square iron rod or perpendicular slider, which at the lower end has the piercer or awl screwed into it: one of the sockets guides the upper part of the slider, and the other the lower part, so that it has a freedom of motion in a perpendicular direction, but no other. The slider is caused to descend by means of a treadle moving on a centre pin, attached to the foot of the iron column, beneath the bench: from this treadle an iron rod ascends through a hole in the

bench (and also through holes in the arms, which project from the column to sustain the slider), and at the upper end this rod is connected with a lever, which moves on a joint at the upper end of the iron column, whilst the extreme end of the lever is connected with the top of the perpendicular slider. By this arrangement it is clear, that the foot, being pressed upon the treadle, will communicate motion by the iron rod and upper lever to the slider and piercer, and force its point through the leather, which is placed upon the small iron table. A short lever and counterpoise are provided to raise up the slider again the instant the pressure is removed. To prevent the piercer striking upon the iron of the table, and breaking the point, a screw is inserted in a piece projecting from the slider, and its point in descending comes to rest upon the upper of the two arms which sustain the slider, and thus stops the descent of the slider at the proper place.

The piece of leather for the sole is fixed upon a pattern made of iron plate, cut to the same size and shape as the sole, which is united to it by two sharp gauge pins, which are fixed in the pattern, one at the middle of the tread, and the other in the centre of the heel; and these pins project so far, that they will just penetrate through the leather, to hold it fast against the pattern, which is perforated with all the holes which are intended to be pierced in the sole. The leather is applied upon the pattern, and struck with a mallet, so as to force the gauge pins into the leather, and unite the sole and the pattern together; the pattern is then laid flat upon the table of the machine, with the leather uppermost, and is brought beneath the joint of the piercer, so that it will penetrate in the desired place. To ascertain this place, a small stud or pin is inserted into a hole in the table, in the exact spot where the point of the piercer descends; the stud projects a little above the surface of the table, but is only held up by a spring, so that it can easily be pressed down. The pattern being placed so that any of the holes therein receive the point of the stud, it is evident that when the pressure of the foot makes the piercer descend, its point will make a puncture in the leather which is fastened upon the pattern, which puncture will be opposite to the hole in the pattern; and though it perforates the leather quite through the thickness, the point of the piercer cannot be blunted against the iron, because it is received in the hole in the pattern, and the stud descends by the pressure, so that the pattern will lie quite flat upon the surface of the table. In this manner the workman pierces any number of holes in the leather, placing it beneath the point of the piercer by the aid of the pattern, and then pressing the foot to bring the point down and pierce the hole. As soon as the piercer rises, he removes the pattern to another hole, and so on. A small piece of iron is fixed just above the leather, which prevents its being lifted up, and following the piercer when it rises. The piercer passes through a hole in this piece.

Nailing Machine for the Short Nails.—The sole being thus pierced with holes, the short nails are put into it by a very curious machine, which at the same time forms the nails, by cutting them off from the end of a strip of iron or copper, of the same breadth as the length of the intended nails.

The sole is presented to the machine by laying it upon a small table, similar to the last machine, and is directed by means of the same pattern; so that each of the holes in the leather will be successively brought beneath the point of a blunt piercer, which descends by the action of a treadle. In the upper part of the machine is a pair of shears, to cut the nails; they consist of a lever, loaded at the extremity with a weight, and connected with the treadle, so that the end of the lever is lifted up when the treadle is depressed by

the foot. Near the centre of this lever is a cutter, which is fixed to it, and moves with it. Another cutter is supported by the frame, so as to be stationary, and in the proper situation to come in contact with the edge of the moving cutter, when the end of the lever is lifted up. The cutters act in a manner similar to a pair of shears, to cut off a small piece from across the end of a slip of iron, which is introduced between the cutters. This piece forms the nail or rivet, which is to be put into the hole in the leather; and immediately after it is cut, it falls into a tube, by which it is conducted down to a small cell or tube, situated immediately over the leather. In this the nail stands perpendicular, and ready, when the piercer descends, to be forced down into the hole in the leather; because the cell which receives the nail is exactly beneath the point of the piercer, so as to hold it perpendicularly in the proper situation. The workman is seated before the machine, and with his right hand directs the sole, with its pattern beneath the piercer, in the same manner as before described. In his left hand he holds the strip of iron or copper which is to make the nails; and he introduces the end of it through a small hole, which conducts to the cutters, pushing it forward with a gentle force: this causes the end of the strip to enter between the cutters, when the shears are open. Then adjusting the sole by the pattern, so that one of the holes in the leather will be beneath the nail contained in the cell, he presses down the treadle: this forces the nail down from the cell into the leather, by the descent of the piercer, and at the same time closes the shears, and cuts off a nail across the end of the strip. The nail immediately descends by the tube into the cell, where it places itself perpendicularly, and ready to be put in its place in its turn. Thus the machine, at every stroke, cuts a fresh nail to supply the place of that which it puts in the leather by the same stroke. The strip of copper is turned over every time, to form the nails alternately head and point.

When all the nails are put in, they are battered down with a hammer; and as they are but very little longer than the thickness of the sole, this reduces them to an even surface.

Application of the Welt to the Sole.—The welt, or runner, is a narrow slip of leather applied upon the sole, round its edge, to make the sole of a double thickness round the edge, where the upper leather joins to the sole, although the sole is only single within. The welt is made from the feather-edged slips which we have before mentioned, and is fastened to the sole by tacking nails of sufficient length to pass through both the sole and the welt. These nails are arranged all round the circumference of the sole, and the holes are first pierced through the sole by the punching machine, which we have before described, but by a different pattern of iron, which is attached to the sole by its two gauge pins entering the same holes which were made through the leather in the first operation. This pattern is pierced with a row of holes all round the circumference, which are arranged within the former row of rivets, or farther from the edge of the sole; but around the toe and tread of the foot, for half its length, the holes are in double number, or at half the distance that they are in the heel part. This pattern being used in the same manner as before described, the punching machine pierces the sole with holes, exactly corresponding to it; which holes are filled with tacking nails in a separate machine, something similar to the nailing machine before described. But as the nails are longer, it would be too laborious to cut them by the same motion; the nails are, therefore, cut by a machine made on purpose, and applied to the leather by

The nailing Machine for long Nails.—This is made exactly the same as the punching machine before described, but with additional apparatus to supply the nails, and put them into the holes. Thus it has a vertical column, with a table and two projecting arms to support the perpendicular slider, which is caused to descend when the foot is applied upon the treadle, and to re-ascend by the action of the counter-weight. The piercer at the lower end is not sharp-pointed, not being intended to penetrate the leather, but only to force the nails into the holes previously pierced by the preceding operation. The additional parts are as follow: a circular plate, or wheel of brass, about nine inches diameter, and of a thickness nearly equal to the length of the nails; it is perforated with a great number of holes, to contain the same number of nails; the holes being made round its circumference, as close together as convenient, and arranged in four circles, one within the other. The interior space within the circles is formed with six arms, like a wheel; and in the centre is a hole, which fits loosely upon an upright centre pin, standing in the centre of a small circular table, which is fixed sideways to the upper of the two arms, which, as before mentioned, project from the vertical column of the machine, and sustain the upper end of the perpendicular slider. Upon this circular table the wheel is supported in a horizontal position, at the height of 18 or 20 inches above the table on which the leather is placed, and with liberty to turn upon its centre pin. The wheel is filled with nails when it is used, one being put into every hole of its circumference, with the points downwards; and the holes are sufficiently large to let the nails drop through the wheel, except when their points rest upon the circular table which supports the wheel. At one part of the circumference of this table an opening is cut through it, and a small tube descends from it, to conduct a nail down to the point of the piercer. The motion of the wheel upon its centre brings the nails successively over the opening or mouth of the tube; and therefore each nail, in its turn, drops by its weight through the hole in the wheel into the tube, which is made so small, that the nail must descend with its point downwards, and fall into a small cell, so situated that the nail will stand exactly beneath the point of the piercer, when the same is at its highest position. But when the piercer is depressed by the action of the treadle, its point will act upon the head of the nail, and force it down through the cell into the leather placed upon the table of the machine; the hole in the leather having been previously pierced by the punching machine. The cell which receives the nail is very ingeniously contrived to hold it in a perpendicular direction, beneath the end of the piercer. It is situated immediately above the leather, and is conical within, so that the nail drops down into it until it becomes fixed fast; but when the nail is to be forced down by the piercer, the cell opens in two halves, being formed by notches in two pieces of steel, which are only held together by being screwed together at one end, and are made so thin as to spring together, and form a cell for the reception of the nail, although they will readily separate when the piercer forces down the nail. It is during the ascent of the piercer that another nail is dropped down from the wheel through the tube, and received into the cell, whilst its two halves are still kept open by the piercer; or rather as the piercer at this moment occupies the interior of the cell, the nail is received in the space, or open joint, at which the two halves of the cell separate, so that the nail lies close by the side of the piercer. But when the piercer has risen up completely out of the cell, its two halves spring together, and the joint in which the nail is placed being formed with faces inclining

inwards, they throw the nail into the cell itself, in which it drops down till it sticks fast; because, as before stated, the cell is smaller at the bottom; and in this situation the nail is certain to be held perpendicular, with its head under the point of the piercer.

To turn the wheel round, so as to supply a fresh nail every time that one has been put into the leather, the edge of the wheel is cut into ferrated or sloping teeth; the number of teeth being equal to the number of holes made in each of the four circles to contain the nails. A small detent or click takes into these teeth by a hook, so that it will turn the wheel when moved in one direction, but slide over the teeth when moved in the other direction. The click is jointed to a short lever, fixed upon the upper end of an upright axis, which passes down through the two projecting arms of the main column, so as to be very near the perpendicular slider; and a short lever, fixed to this axis, bears, by the action of a spring, against a wedge fixed to the slider. The action of this mechanism is to turn the wheel round one tooth at a time: thus, when the slider descends, its wedge forces the end of the short lever farther away from it; this movement is communicated by the upright axis and upper lever to the click, which slides over the sloping sides of the teeth of the wheel; but on the re-ascent of the slider, the wedge allows the lever and click to return by the action of a spring, and the hook of the click, having caught a tooth of the wheel, will turn the wheel round the space of one tooth. In this manner, at every descent of the slider the click engages a fresh tooth of the wheel; and at every ascent, the wheel is turned round upon its centre pin; the weight of the wheel, resting upon the flat circular table, being sufficient to retain it as it is placed.

The nailing machine acts with the same rapidity as the other machines, to put a nail into every one of the holes previously made; and for this purpose the leather is kept upon the same pattern by which those holes were pierced, not only for the purpose of placing the leather so that the nails shall be inserted into those holes, but that the thickness of the pattern may allow the nails to penetrate and project through the leather on the under side. When the nails are all put in, they are beat down with a hammer, to drive all the heads to a level with the surface. The leather is then separated from the pattern, and put into a frame called

The welting Stand.—This machine is a small square table of cast-iron, fixed on the top of a pedestal, in which it is capable of turning round, for the convenience of the workman, and to enable him to work at the different sides, as he remains seated before the table. An iron frame is connected with the table by hinges at one side, so that it can be lifted up or turned down, to lie flat upon the surface of the table; and in this situation it can be fastened down by means of a simple clamp. This frame is intended to hold fast the leather which is placed beneath the frame: the interior opening of the iron frame is nearly of the same size and shape as the sole of the shoe. The sole is placed flat upon the table, in the proper position, which is determined by two gauge pins fixed into the table, and entering the holes made in the sole; then the iron frame being turned down upon the leather, will inclose the sole as it were with an iron hoop, or raised border, all round the edge; and the frame being clamped fast down, the sole is confined, as if lying in the bottom of a cell of iron, of the same figure as itself, and with the nail points projecting upwards from the sole. In this frame the welt is applied, by laying the strip of leather upon the edge of the sole in contact with the inside of the iron frame, and bending it to follow the curves of the outline of the sole. As fast as any part of the length of the

strip is settled to its position, it is attached to the sole by striking it down with a mallet upon the points of the nails. The thin or feathered edge of the strip of leather is put inside, so that the edge of the sole, for about the breadth of half an inch, is of a double thickness; but within this, the extra thickness diminishes away to nothing, leaving only the thickness of the sole. The ends of the strip of leather which compose the welt, where they join and complete the circuit of the sole, are cut sloping, so as to lap over each other, and make a joint, without any increase of thickness, or apparent division. When the sole is taken out of this frame, the welt and sole are beat well down together, to make a good joint; it is then carried to the cutting press, in which the edge or outline of the sole and welt are cut smooth, and to the same size; because, as the frame of the welting machine must be rather less than the sole, in order that the frame may bear upon the edges of the sole all round, and thus hold it fast, the welt, which is moulded or bent round within the frame, will be a small quantity less all round than the sole. To guide the knife in cutting round the edge of the sole, it is confined between two iron patterns, which are made exactly to the size to which the edge is to be pared. They are attached to the sole by two gauge pins, fixed into one of the plates, and passing through the holes in the sole, project far enough on the opposite side for the other plate to be fastened on, in its required position, by two holes which receive the ends of the pins.

The *cutting-press* very much resembles a common lathe: a horizontal spindle is supported in a frame, consisting of two standards, erected from a horizontal plate, to sustain the spindle, which passes through a collar in one of these standards, and projects some inches beyond it, having at the extremity a piece of wood flat on the surface, and of the same shape as the sole. Against this flat surface the two iron plates, with the sole between, are placed, and they are forcibly pressed together by the action of a screw, fitted into a third iron standard, erected from the same horizontal plate, and pressing by means of a lever upon the iron plates exactly opposite the end of the spindle. This pressure causes the spindle to retreat a small quantity in the direction of its length, and then a flat circular plate, fixed upon the spindle, (in the same situation as the pulley of a common lathe,) is made to press against a similar flat plate, which is fastened to the frame, and therefore cannot turn round. By the friction between these two surfaces, the spindle becomes immovable, and the press holds the sole firm, whilst the workman, who is seated before the machine, cuts all round the edge with a drawing-knife, which is made sharp in the middle, and is worked with both hands by having a handle at each end. When he has with this tool pared down that part of the edge which is uppermost, he releases the screw of the press, and a spring then causes the spindle to advance so far as to relieve the flat circular plate, which is fixed upon the spindle, from its contact with the fixed plate. This leaves the spindle at liberty to be turned round, and the sole turns with it, so as to bring up a new part of the edge of the leather to a convenient situation to be pared or cut; and the screw is then turned to fasten the spindle as before described, and at the same time to press the sole between the two patterns.

When the edge of the sole is thus cut, it is carried to a grindstone, and ground smooth: the stone is turned with a quick motion, by means of a band and large wheel; the leather is afterwards polished by applying it to the edge of a wooden wheel, on which a little bees-wax is spread.

Application of the long Nails.—The sole, thus re-inforced by the welt, is returned to the punching machine, and be-

ing attached to another pattern, a range of holes is pierced all round the outer edge, through both, just within the former row of tacking nails; after which, by the nailing machine, these holes are filled with nails which project through the upper side of the welt, being longer than any of the former, and being also intended to penetrate through the upper-leather and inner soles, and thus fasten the shoe together. In this state the sole is ready to be put to the upper-leathers.

The *upper-leathers* are prepared for applying to the sole, in the same manner as the ordinary shoe, viz. by sewing the vamp, or piece which covers the upper part of the foot, to the two quarters which go round the heel, and also sewing these two quarters together behind the heel. The workmen do not hold the work upon their knees to sew it, but four men work at a square table, the corners of which are cut off, and a small piece of wood projects from each angle: the two pieces of leather which are to be sewed together are laid upon one of these pieces of wood in the proper position to be sewed, and are held fast by an endless strap, which is laid over them, and the workman binds it fast down, by pressing his foot in the strap, like a stirrup. This method of sewing, which is far superior to the common mode, might, from its simplicity, be used by all shoe-makers, and would render their business less unhealthy; whereas at present they are subject to many diseases from sitting in the awkward and unnatural posture which is necessary to reach their work, when they hold it upon their knees.

Operation of closing or rivetting the Shoe together.—The upper-leathers are put upon a last, and held tight thereupon whilst the sole is applied. This is done in

The Clamping Machine.—It is a small oval table, supported on a column, but capable of turning round upon the column, to enable the workman to work at any side. In the centre of the table a last is fixed, with the sole upwards; it is supported at a height of about six inches from the table. The sole is made of cast-iron, in a solid piece, with the stem or part by which the last is supported; but the under part, upon which the upper-leathers are to be moulded, is made of wood, for the convenience of altering the figure when necessary. The last is fixed upon the table by means of two steady pins; and a strong pin, which projects from the lower part of the last, and passes through the table, is bound fast by a wedge, which confines the last firmly upon the table, in the same manner as if it was made in a piece therewith. The table has a number of pieces of brass attached to it by hinges, and arranged all round the last in such a manner, that they can be turned up against the lower part of the last, and then form clamps, which are exactly adapted to the figure of the lower part of the last, and will therefore clamp or bind the leather firm upon the last at the toe, heel, and every part thereof, except at the flat part of the sole. The brass clamps are of such dimensions, that they will touch each other when turned up, and thus form a complete cell or box, in which the lower part of the last will be contained, and the leather confined upon it; but the cell being made in several pieces, or clamps, they can be removed one by one, as found necessary. The clamps are forced up to their situation by means of an independent screw for each, which is tapped in an oblique direction through the edge of the table, and the point forces up the end of a small rod, which is jointed to the clamp near the part where it acts upon the leather: by this means the force of the screw acts to turn the clamp up upon its hinge, and at the same time presses it against the leather. When the pressure is released by displacing the end of the small rod from the point of the screw, the clamp will be suffered to fall back upon the table; and this being

Jone to all the clamps, the last stands insulated in the middle of the table, from which it can be detached by withdrawing the wedge which confines it. The inner sole of the shoe is first put upon the sole of the last, being slightly fastened thereto by two short pins, one of which is driven through the gauge hole in the toe of the sole, and enters a hole made in the last; and the other pin is fixed in the heel part of the last, and enters the hole in the sole. The upper-leathers are now put upon the last in the true position. In this state, the last is taken to the clamping machine, and fastened into its place in the centre of the table; the clamps are then turned up, one by one, beginning at the heel, and the upper-leathers being pulled up all round by a pair of pincers, so as to make them fit tight upon the last, the clamps are screwed tight. In this state, the upper-leathers are made to take the form of the last, being firmly attached thereto, except at the sole part: at this part the leather stands up all round about three-quarters of an inch, which quantity is turned down flat upon the edge of the inner sole (previously fastened upon the sole of the last), and a small quantity of paste is put in to make it stick fast: four or five notches are cut out in the leather at the toe and at the heel, to make the part which is turned down lie flat upon the sole, without folds or overlapping, and then, to make a close contact, the leather is beaten down. Parings of leather are likewise patted, and stuck flat upon the inner sole for levelling, to make up the sole to the same thickness in the centre as it acquires towards the edges all round by the turning-in of the upper-leathers. In this state, the nail which fastened the inner sole to the last is withdrawn, being now unnecessary, and the real sole is applied, an iron frame, or saddle, being employed to determine its proper position upon the last. This frame is made of thin iron, and its figure within is similar, and of the same size as the row of nails which project through the sole, and by which the sole is to be rivetted into its place: it is made in two halves, which are united by a joint or hinge at the heel part; and at the toe part are two holes, through which a pin can be put to hold the frame together. This pin, as well as the joint pin of the hinge at the heel, projects downwards sufficiently to enter into a hole made in each of the two clamps at the toe and heel, in such a position as to guide the frame, so that it will apply the sole exactly in the proper position.

The sole, when prepared as before described, by inserting all the long nails in the holes, so that their points project through the leather, is put into an iron box or mould, and a plate being laid upon it, is put into the fly-press, and by a single blow the sole is rendered concave within, so as to adapt itself to the last. When it is taken out of the mould, the iron frame before-mentioned is put together round the row of nails, the size of the inside of the frame being made exactly of the proper size to receive the projecting points of the nails, and retain them perpendicular to the leather, and prevent them from spreading out. The sole is then applied in its place by the two guide pins of the frame, and by striking upon the heads of the nails, their points penetrate through the turning-in of the upper-leather, and also through the inner sole. When they are well entered the iron frame is taken away, by withdrawing its pins, and opening its two halves on their joint, and the nails are driven down into their places. This causes them to project through the inner sole into the shoe, and the points meeting the iron last are turned back, and thus clenched into their places. To render this more certain, the sole of the last is made with a slight groove all round, where the points of the nails will fall, and the groove

being of a semicircular figure, the points are more readily turned thereby, and are all turned the same way, so that they will not interfere.

The shoe is now put together, and the clamps being relieved and turned down, the shoe is taken off the last; for which purpose the heel of the last is made in a separate piece, and jointed to the other by inclined fittings, and with a tongue or rebate, so that it can be held fast in its place by a single hook or spring catch; but this being relieved, the shoe draws off the last with the greatest ease, the heel part remaining within the shoe, and is taken out afterwards. The shoe is now carried to the *rivetting last*, where it is put upon a last exactly similar to that of the clamping machine, but fastened down upon a bench, and the sole is smooth without the groove, which caused the points of the nails to turn up. Upon this last the nails are beaten down, to rivet all fast, and make the sole smooth within: the heel is then put on by laying it in its place, and driving down the long nails which have been put through it by the nailing machine, in the same manner as for the sole.

The sole of the shoe is now rasped with a coarse file, to level all the nail-heads, and render the leather smooth; the shoes are then carried to the grindstone, by which they are polished, and finished up in every part, the soles blacked, and polished by the wheel with a composition of bees-wax and ivory black, which renders them glossy: the upper-leathers are then brushed by a circular brush, which is turned by the lathe, and the shoes are rendered fit for sale, except those which require binding and lining, with a lining of thin leather, in which case they are finished in the same manner as common shoes.

Nail Machine.—This is equally deserving of notice with any other part of this ingenious manufactory. In our article *NAIL* we have described some nail machines; but we consider this as a much better machine for cutting brads or nails without heads. The nails are cut from sheet-iron, the plates being first reduced into slips, of a breadth equal to the length of the intended nails, by a large pair of shears, acting in the same manner as those described in the article *CANTEN*, but are constructed in a superior manner, by employing cast-iron for the framing and for the lever. The iron plate is presented to the machine by one man, whilst another works the handle, and at a single stroke cuts off the desired strip of iron: the sheet of iron is cut so that the direction of the grain, or fibrous texture which the iron acquires by rolling, will be across the length of the strip. From this it follows, that when the nails are formed by cutting off narrow pieces from the end of the strip, the grain of the iron will be the lengthwise of the nail.

The *cutting of the nails* is readily performed by the machine, which is turned by the foot of the workman, whilst he supplies the iron by his hands. The motion of the treadle turns a crank and heavy fly-wheel, similar to the wheel of a lathe: from the same crank a rod proceeds to the longer end of a stout lever, the axis of which is supported on pivots in the upper part of the frame, so as to be above the wheel and crank. At a small distance from the centre of the lever, and at the opposite side of the axis to the long lever, a steel cutter is fixed, which acts against a fixed cutter supported by the frame; the fixed cutter has an edge on the upper side, and the moving cutter, which is fixed to the lever, is made sharp on the lower side. The revolution of the wheel and crank causes the lever to rise and fall, and the edges of the two cutters in this motion pass as close together as possible, without touching. At the most elevated position of the moving cutter, its edge rises above the edge

of the fixed cutter so far, that the thickness of the strip of plate can be admitted between them; the end of the strip is pushed back, so that a small portion of the end of it overhangs the edge of the fixed cutter; therefore the edge of the fixed cutter, when it descends, meets this overhanging piece, and pressing it down upon the edge of the fixed cutter, cuts it off, and the piece so separated forms a nail. When the moving cutter re-ascends, the iron is pushed forwards again to overhang the fixed cutter, and another nail is thus cut off. The nails are narrow at one end to form the point, but at the other end are about as broad as the thickness of the plate, so as to be of a square figure; but at the point they are, in one direction, as broad as at the head; this is the direction of the thickness of the plate, so that in reality the nail is the figure of a small wedge instead of a pyramid, the point being in fact a sharp edge. To effect this, the cut which the machine makes across the end of the strip of iron is not perpendicular to the length of the strip, but rather inclined thereto; and at every successive nail which is cut, the inclination of the cut is reversed, so that the head of one nail is cut from the same side as the point of the next, and so on alternately of the whole length of the slip of iron. The thickness of the nail is regulated by the quantity which the end of the slip is allowed to project over the edge of the fixed cutter, and the angle of inclination by two stops, against which the edge of the slip is always brought to bear, when the workman places it ready for the cut. To stop the end of the iron, a part projects from the lever beneath the edge of the moving cutter, and is curved to the arc of a circle described from the axis: this stop is as far removed behind the edge of the cutter as the thickness of the nail intended to be cut off by the descent of the moving cutter. In working the machine, the workman keeps the wheel constantly revolving by the motion of the treadle; and holding the slip with its edge in contact with the two stops, so as to give it the proper inclination, he pushes it forwards, with a gradual pressure, against the moving cutter: then the instant the cutter is sufficiently raised to admit the slip, it will advance forwards, until the end of the slip touches the stop which is beneath the cutter: on the descent of the cutter, the nail is cut off, and the workman immediately turns the slip with the other side upwards, which has the effect of reversing the inclination of the cut; and pushing it forwards, another nail is cut as the former, and thus the operation continues with the utmost rapidity.

There are several suits of machines in this manufactory, so that a great number of shoes are proceeding at the same time through the different stages of their fabrication; and the rapidity of the execution is such, that a given number of workmen will here make a far greater number of shoes than by the common method, and they are more durable, particularly for the strong shoes which are desirable for soldiers. Several of the machines were constructed by Mr. Maudslay, with his usual accuracy of execution.

Shoe-makers' Machine.—This is a simple contrivance, to enable those artificers to perform their work in a standing posture; by which means they will avoid the diseases incident to those who follow sedentary employments.

In the common method of working, the shoe-maker is obliged to sit and stoop in the most awkward posture imaginable, sometimes in order to hold the shoe and last between his stomach and his thigh, whilst he sews the sole to the upper leather; at other times he must hold the last between his knees; and to sew the leathers together whilst he holds them upon his knees, he must lean very much forwards. In all these operations he sits as it were doubled up, so as to

impede the action of his lungs, and ultimately produce many diseases. The machine is a kind of vice, to hold the shoe in any position whilst it is sewed.

The Society of Arts have shewn a laudable desire to recommend these machines to the trade; and to induce their general adoption, they have given several rewards to those who have produced machines. The first of these was Mr. Holden, then Mr. Parker, and next Mr. Stals, whose machine, being more improved than the preceding, demands some description. A small bench, or table, is firmly supported on four legs, at about four feet from the ground; a circular cushion is affixed upon the bench, having a hollow or basin in the centre of it, with a hole from the bottom of the hollow, quite through the cushion, and also through the centre of the bench. This hole receives a strap, which is doubled, and the two ends sewed together. The last is put into the double of the strap, and it is drawn down by a treadle, so as to hold the last firmly in the hollow of the cushion, which is stuffed soft within; and as the hole through the cushion is too small for the shoe to pass down, the last can be set in any direction which is most convenient for the sewing; but by relieving the treadle, it can be removed in an instant, turned round, and fixed again to sew another part. A seat can be applied in front of the machine, for the workman to rest himself occasionally: this seat is supported by only two legs, and a piece of wood, which projects horizontally from beneath the seat, and enters into a mortise, made in a part of the frame. Upon this the workman sits altride, as if upon a saddle; and as his work is held before him at a proper height, he sits in an upright posture, which is not attended with the same prejudicial effects as stooping to work upon the knee. The machine is provided with a small tray, or box, behind the cushion, to contain all the small articles which the work requires; also a drawer beneath it for tools, &c.; a whetstone fixed up at a convenient height; and an anvil, which fits into the hollow of the cushion, so as to lie firmly, to hammer the leather upon instead of a lapstone.

Shoe-makers are to make their shoes of sufficient leather, or forfeit 3s. 4d. (1 Jac. I. c. 22.) and journeymen shoe-makers embezzling leather shall make satisfaction for damage, or be ordered by justices to be whipped, &c. Persons buying or receiving such leather, are to make reasonable recompence, to be levied by distress, &c. and search is to be made after the same: also leaving their work undertaken, or neglecting it, to be sent to the house of correction for a month. 9 Geo. I. cap. 27. 13 Geo. II. c. 8. See LEATHER.

SHOE, in the *Manege*. A horse-shoe is a piece of flat iron, with two branches or wings, which being commonly forged according to the form of the hoof for which it is designed, is made round at the toe, and open at the heel.

A shoe for all feet, is one that is cut at the toe into two equal parts, which is joined by a rivetted nail, upon which they are moveable in such a manner, that the shoe is enlarged or contracted less or more at pleasure, in order to make it fit all sorts and sizes of feet.

To shoe a horse after the form of a lunette, a patin, &c. see LUNETTE, PATIN, &c. See also SHOEING of Horses, &c.

Berenger observes, that the ancients did not shoe their horses, that is to say, they did not nail upon their hoofs any pieces of iron, or of other metal, in the form of the modern horse-shoes: but when they intended to defend them from any thing that might annoy them in travelling, they fastened upon their feet, by means of straps and ligatures, a sort of sandal, stocking, or what we call boots.

These were made of sedges twisted together like a mat, or else of leather, and were sometimes strengthened with plates of iron, and adorned by the rich and ostentatious with silver and gold, as in the instances of Nero and Poppæa.

It does not appear in what era, or in what country, the modern art of shoeing took its rise. The earliest proof which the above mentioned writer has met with is the shoe said to have belonged to the horse of Childeric, who lived in the year 481, and is preserved in Montfaucon's *Antiquities of France*. It perfectly resembles the shoe now in use. Berenger's *Horsemanship*, vol. i. p. 234.

SHOES of the Horse and other Animals, the crooked pieces of iron attached to the hoof of the horse or other beasts, by means of nails. There are various forms and shapes of shoes in common use, and others which are adapted and accommodated to the particular purposes and circumstances of the hoofs. Different sorts of animals, likewise, require different forms in their shoes. In speaking of the shoe which is *concave* on its *lower surface*, it has been remarked by some, that there are certain proportions to be observed in its different parts. Its breadth should be considerably less than the breadth of the common shoe; it is totally unnecessary to cover any part of the sole, especially when care is taken to preserve its natural hardness. The breadth of the shoe at the heels should be one-half of its breadth at the toe. Its thickness should decrease gradually from the toe, so as to be reduced one-half at the extremity of the heels. As to the distribution of the stamp-holes, every person acquainted with the subject knows, that in shoes for the fore-feet, they should be at the toe and quarters, because the wall, or crust, of the fore-feet is stronger at the toe than at the heels. The reverse of this is to be observed in the hind shoes, because the heels and quarters of the hind-feet are commonly stronger than the toe. It is impossible to lay down any general rule for disposing of these holes in bad feet; it must be the business of the farrier to distribute them in such a manner, as to be able to fix the nails in those parts of the crust where the horn is found and firm. Farriers generally multiply these stamp-holes too much, which brings the nails too close together, occasions the horn to break in splinters, and at length destroys the crust.

The following number is recommended for good feet; *viz.* for race-horses six, that is three on each side; for saddle-horses seven, four on the outside and three within, the quarter on this side being weaker than on the other; the

same number for coach-horses of the middling size; for large coach-horses four on each side; and for cart-horses, five on the out and four on the inside. It is also of principal importance to determine the *weight of the shoe*, for it is matter of astonishment, to see some horses with shoes weighing each five pounds, making together a burden of twenty pounds of iron attached to their four feet. It is obvious to common sense, that such an additional weight, fixed to the extremity of the leg, must be productive of some inconvenience or other; and, in fact, the muscles are thereby compelled to greater exertion; the ligaments are stretched, and the articulations continually fatigued: and, besides all these evil consequences, the shoe by its weight forces out the nails, and so entirely spoils the texture of the wall or crust, that it becomes often extremely difficult to fix the shoe to the hoof. Why then, it is asked, do not practitioners of the present day, who are daily witnesses of these facts, and indeed are the principal authors of them, apply themselves to the correction of their own errors? The answer, it is feared, is obvious: because he who is uneducated and destitute of sound principles in his art, cannot turn to real profit the experience he has acquired, nor abandon the path of prejudice and custom, in which he has so long journeyed, but satisfies himself with continuing to imitate and repeat whatever he has seen done by others.

The weights which are proposed, for shoes of different kinds, are nearly as follow:

	lb.	oz.
For the strongest sort of cart-horses	-	2 12
For the smaller horses of this kind	-	1 12
For the largest coach-horses	-	1 12
For the smaller ditto	-	1 4
For saddle-horses of any height	-	2 to 10
For race-horses	-	0 4 to 5

And by reducing the superfluous breadths of these shoes, their thickness may, it is supposed, be increased without making any addition to their weight. See **SHOEING**.

SHOES of Cattle, the small plates of iron that are fastened upon the feet of oxen, or other cattle employed in field or road labour. Shoes of this sort consist, according to some, of a flat piece of iron, with five or six stamp-holes on the outward edge, to receive the nails: at the toe is a projection of some inches, which passing in the cleft of the foot, is bent over the hoof so as to keep the shoe in its proper place. This projection is not, however, employed in the general practice of making these shoes, nor can it in common be of any utility. See **SHOEING of Oxen**.

Silk

SILK, SERICUM, a very soft, fine, bright, delicate thread; the work of an insect, called *bombyx*, or the silk-worm.

The ancients were but little acquainted with the use and manufacture of silk; they took it for the work of a sort of spider, or beetle, who spun it out of its entrails, and wound it with its feet about the little branches of trees. This insect they called *ser*, from *Seres*, a people in Scythia, whom

we now call the Chinese, who, as they thought, bred it; whence the silk itself they called *sericum*. But this *ser* of theirs has very little affinity with our silk-worm, *bombyx*: the former living five years; but the latter dying annually, enveloped in a yellowish bag or ball, which, wound out into little threads, makes what we call silk.

It was in the isle of Cos that the art of manufacturing it was first invented; and Pamphila, daughter of Platis, is honoured as the inventress. The discovery was not long

unknown to the Romans. Silk was brought them from Serica, where the worm was a native. But so far were they from profiting by the discovery, that they could not be induced to believe so fine a thread should be the work of a worm; and thereupon formed a thousand chimerical conjectures of their own.

Silk was a very scarce commodity among them for many ages: it was even fold weight for weight with gold; inasmuch that Vopiscus tells us, the emperor Aurelian, who died A.D. 275, refused the emperors, his wife, a suit of silk, which she solicited of him with much earnestness, merely on account of its dearth.

Others, however, with greater probability, assert that it was known at Rome so early as the reign of Tiberius, about A.D. 17.

Galen, who lived about the year of our Lord 173, speaks of the rarity of silk, being no where but at Rome, and only among the rich.

Heliogabalus, the emperor, who died A.D. 220, is said by some to be the first person who wore a holosericum, *i. e.* a garment of all silk.

The Greeks of Alexander the Great's army are said to have been the first who brought wrought silk from Persia into Greece, about 323 years before Christ; but the manufacture of it was confined to Berytus and Tyre, in Phœnicia, whence it was dispersed over the West.

At length, two monks, coming from the Indies to Constantinople, in 555, under the encouragement of the emperor Justinian, brought with them great quantities of silk-worms, with instructions for the hatching of their eggs, rearing and feeding the worms, and drawing out the silk, and spinning and working it. Upon this, manufactures were set up at Athens, Thebes, and Corinth. The Venetians, soon after this time, commencing a commerce with the Greek empire, supplied all the western parts of Europe with silks for many centuries; though sundry kinds of modern silk manufactures were unknown in those times, such as damasks, velvets, satins, &c.

About the year 1130, Roger II. king of Sicily, established a silk manufactory at Palermo, and another in Calabria; managed by workmen, who were a part of the plunder brought from Athens, Corinth, &c. of which that prince made a conquest in his expedition to the Holy Land. By degrees, Mezeray adds, the rest of Italy and Spain learned, from the Sicilians and Calabrians, the management of the silk-worms, and the working of silk; and at length the French got it by right of neighbourhood, a little before the reign of Francis I., and began to imitate them. Thuanus, indeed, in contradiction to most other writers, makes this manufacture of silk to be introduced into Sicily two hundred years later, by Robert the Wise, king of Sicily, and count of Provence.

It appears by 33 Hen. VI. cap. 5. that there was a company of silk-women in England so early as the year 1455; but these were probably employed in needle-works of silk and thread: and we find that various sorts of small haberdashery of silk were manufactured here in 1482; but Italy supplied England, and all other parts, with the broad manufacture, till the year 1489. In Spain, indeed, the culture and manufacture of silk seem to have been introduced in an early period by the Moors, particularly in Murcia, Cordova, and Granada. The silk manufactures of this last town were very flourishing, when it was taken by Ferdinand, &c. at the close of the fifteenth century.

In 1521, the French, being supplied with workmen from Milan, commenced a silk manufacture; but it was long after this time before they could obtain raw silk from the

worms; and even in the year 1547, silk was scarce and dear in France; and Henry II. is said to have been the first who wore a pair of silk knit stockings; though the first invention originally came from Spain, whence silk stockings were brought over to Henry VIII. and Edward VI. After the civil wars in France, the plantations of mulberry-trees were greatly encouraged by Henry IV. and his successors; and the produce of silk is at this day very considerable.

The great advantage which the new manufacture afforded, made our king James I. very earnest for its being introduced into England: accordingly it was recommended several times from the throne, and in the most earnest terms, particularly in the year 1608, to plant mulberry-trees, &c. for the propagation of silk-worms; but unhappily without effect; though from the various experiments we meet with in the Philosophical Transactions, and other places, it appears that the silk-worm thrives and works as well, in all respects, in England, as in any other part of Europe.

However, towards the latter end of this king's reign, *i. e.* about the year 1620, the broad silk manufacture was introduced into this country, and prosecuted with great vigour and advantage. In 1629, the silk manufacture was become so considerable in London, that the silk-throwsters of the city, and parts adjacent, were incorporated under the name of master, wardens, &c. of the silk-throwsters; and in 1661, this company of silk-throwsters employed above forty thousand persons. The revocation of the edict of Nantes, in 1685, contributed in a great degree to promote the silk manufacture in this kingdom; as did also the invention of the silk throwing machine at Derby, in 1719; for an account of which, see *SILK, Manufacture of*.

So high in reputation was the English silk manufacture, that even in Italy, as Keyser (*Travels*, vol. i. p. 289.) informs us, in 1730, the English silks bore a higher price than the Italian.

The silk-worm is an insect not more remarkable for the precious matter it furnishes for divers stuffs, than for the many forms it assumes, before and after its being enveloped in the rich cod or ball which it weaves for itself. From a small egg, about the size of a pin's head, which is its first state, it becomes a pretty big worm, or caterpillar, of a whitish colour, inclining to yellow. In this state it feeds on mulberry-leaves, till, being come to maturity, it winds itself up in a silken bag, or case, about the size and shape of a pigeon's egg; and becomes metamorphosed into an aurelia: in this state it remains without any signs of life, or motion; till at length it awakes to become a butterfly, after making itself a passage out of its silken sepulchre; and, at last, dying indeed, it prepares itself, by an egg which it casts, for a new life; which the warmth of the summer weather assists it in resuming.

As soon as the silk-worm, or caterpillar, is arrived at the size and strength necessary for beginning his cod, he makes his web; for it is thus they call that slight tissue, which is the beginning and ground of this admirable work. 'This is his first day's employment. On the second, he forms his folliculus, or ball, and covers himself almost over with silk. The third day, he is quite hid; and the following days he employs himself in thickening and strengthening his ball; always working from one single end, which he never breaks by his own fault; and which is so fine, and so long, that those who have examined it attentively, think they speak within compass, when they affirm that each ball contains silk enough to reach the length of six English miles.

In ten days' time, the ball is in its perfection; and it is now to be taken down from the branches of the mulberry-trees, where the worms have hung it. But this business

requires a great deal of attention ; for there are some worms more lazy than others ; and it is very dangerous waiting till they make themselves a passage, which usually happens about the fifteenth day.

The first, finest, and strongest balls are kept for the breed ; the rest are carefully wound. If there be no more than can be well wound at once, they lay them for some time in an oven, moderately hot, or else expose them, for several days successively, to the greatest heats of the sun, in order to kill the insect ; which, without this precaution, would not fail to open itself a way to go and use those new wings abroad, which it has acquired within. Ordinarily, they only wind the more perfect balls. Those that are double, or too weak, or too coarse, are laid aside ; not as altogether useless, but that, being improper for winding, they are reserved to be drawn out into skeins. The balls are of different colours ; the most common are yellow, orange-colour, isabella, or flesh-colour. There are some also of a sea-green, others of a sulphur-colour, and others white ; but there is no necessity for separating the colours and shades, to wind them apart, as all these colours are to be lost in the future scouring and preparing of the silk.

SILK, Manufacture of. In England, where silk is not produced in any quantities to be employed by the manufacturer, he must commence his operations upon the raw silk, with no other preparation than that of being wound off into skeins or hanks from the balls, or cocoons, which the silk-worms form.

In this state the silk is imported from those countries where it is produced, as Italy, Flanders, Spain, Portugal, Turkey, the East Indies, and China. A thread of this raw silk, drawn from the skein, is found to be composed of an assemblage of several of the fine fibres or threads produced by the worms ; the fibres being united together by a natural gum, which is in the silk, and which is soluble in the hot water in which the cocoons are immersed when the silk is wound off.

To prepare this raw silk for use, it is wound from the skeins upon bobbins ; the compound thread is then twisted, to unite the constituent fibres more firmly than they can be by the gum alone ; and afterwards, being wound again upon fresh bobbins, two or three threads are twisted together to produce a stronger thread, fit for the weaver, who warps and finally weaves the silk into various articles of ornaments or utility, by processes very similar to the weaving of cotton or linen, but more delicately conducted.

In the countries where the silk is produced, the manufacture may be more properly said to commence with the operation of winding or reeling off the threads into skeins from the cocoons, or balls, in which the worms envelope themselves. These balls become an article of trade, as soon as the insect within them is killed by exposing them to heat, either of the sun, or in an oven, or by the steam of boiling water ; and, in general, the breeders of silk-worms sell them, in this state, to persons who make a business of the operation of winding. In Piedmont, where capital silk is produced, it is conducted, as follows, by the aid of the silk reel represented in *Plate Silk Manufacture, fig. 1.*

The balls are thrown into hot water, contained in a copper basin or boiler, A, which is about eighteen inches in length and six deep, set in brick-work, so as to admit a small charcoal fire beneath it ; or if a fire of wood is intended to be made, the fire-place must have a small flue or chimney of iron plate to carry off the smoke. At the side of the boiler is placed the reel, which is very simple. BB marks the wood-framing which sustains its parts : these are, the reel D,

upon which the silk is wound ; the layer *a*, which directs the thread upon it ; and the wheel-work *b c*, which gives motion to the layer. The reel, D, is nothing more than a wooden spindle, turned by a handle at the end ; and within the frame, at each end, it has four arms mortised into it, to support the four battens or rails on which the silk is wound. The rails are parallel to the axis, and at such a distance, that they will form a proper-sized skein by the winding of the silk upon them, (it is usually a yard for each revolution.) One of each of the four arms is made to fold in the middle of its length with hinges, so as to cause the rail, which these two arms support, to fall in or approach the centre, and thus diminish the size of the reel, and admit the skeins of silk to be taken off at the end of the reel when the winding is finished.

Upon the end of the wooden spindle of the reel, and within the frame B, is a wheel of twenty-two teeth, to give motion to another wheel, *c*, which has about twice the number of teeth, and is fixed upon the end of an inclined axis, *c b* ; this, at the opposite end, carries a wheel, *b*, of twenty-two teeth, which gives motion to an horizontal cog-wheel of thirty-five teeth. This wheel turns upon a pivot fixed in the frame, and has a pin fixed in it, at a distance from the centre, to form an excentric pin or crank, and give a backward and forward motion to the slight wooden rail or layer *a*, which guides the threads upon the reel : for this purpose, the threads are passed through wire-loops or eyes, *a*, fixed into the layer, and the end thereof opposite the wheel and crank, *b*, is supported in a mortise or opening made in the frame, B, so that the revolution of the crank will cause the layer to move, and carry the threads alternately towards the right or left. There is likewise an iron bar, *e*, fixed over the centre of the boiler at *e*, and pierced with two holes, through which the threads pass to guide them.

To describe the operation of reeling, it should be understood, that if the thread of each ball or cocoon was reeled separately, it would be totally unfit for the purposes of the manufacturer ; in the reeling, therefore, the ends or threads of several cocoons are joined, and reeled together out of warm water, which softens their natural gum, and makes the fibres stick together, so as to form one strong smooth thread ; and as often as the thread of any single cocoon breaks or comes to an end, its place is supplied by a new one, so that by continually keeping up the same number, the united thread may be wound to any length. The single threads of the newly added cocoons are not joined by any tie, but simply laid on the compound thread, to which they will adhere by their gum ; and their ends are so fine, as not to occasion the least perceptible unevenness in the place on which they are laid.

The woman who conducts the reeling is seated before the basin A, and employs a boy or girl to turn the handle of the reel : a fire is lighted beneath the basin A ; and when the water becomes nearly boiling hot, she throws into the basin two or three handfuls of cocoons, and leaves them some minutes, to soften that natural gum with which the silk is impregnated ; then she stirs up or brushes the cocoons with a wisk of birch or of rice-straw, about six inches long, cut stumpy, like a worn-out broom ; the loose threads of the cocoons stick to the wisk, and are drawn out : she then disengages these threads from the wisk, and by drawing the ends through her fingers, cleans them from that loose silk which always furrounds the cocoon, till they come off entirely clean : this operation is called *la battue* : and when the threads are quite clean, she passes four or more of them, if she intends to wind fine silk, through each of the holes in the thin

iron bar *c*, which is placed horizontally over the centre of the basin A; afterwards she twists the two compound threads (which consist of four cocoons each) twenty or twenty-five times round each other, that the four ends in each thread may the better join together by crossing each other, and that the thread of the silk may be round, which otherwise would be flat.

The threads, after passing through the holes in the iron bar *c*, and being twisted together, are passed through the eyes of the loops, *a*, of the layer, and thence being conducted to the reel, are made fast to one of its rails. The child who turns the reel, gives it the most rapid movement possible, and thus draws off the threads from the cocoons in the basin A. The slow traversing motion of the layer prevents the threads lying over each other upon the reel, until it has made so many revolutions in the air as to dry the gum of the silk so far, that the threads will not adhere together. After the reel is covered for about the breadth of three inches, by the gradual progression of the layer, it returns and directs a second course of threads over the first laid, and so on until the required length for the skeins is obtained. The machine winds two skeins at one time. As it is essential to the production of good silk, that the thread should have lost part of its heat and gumminess before it touches the bars of the reel, the Piedmontese are by law obliged to have a distance of thirty-eight French inches between the guides, *a*, and the centre of the reel; and the layer must also, under a penalty, be moved by cog-wheels instead of an endless cord, which is sometimes used in Italy, and which, if suffered to grow slack, will cause the layer to stop and not lay the threads distinctly, and that part of the skein will be glued together, whereas the cog-wheels cannot fail.

When the skeins are quite dry the reel is removed from the frame, and by the folding of two of its arms the skeins are taken off. A tie is made with some of the refuse silk on that part of each skein where it bore upon the bars of the reel, and another tie on the opposite part of the skein; after which it is doubled into a hank, and usually tied round near each extremity, when it is laid by for use or sale.

This operation appears very simple, but to produce a good thread requires much attention. The reeler must not wait until the thread of a cocoon is entirely exhausted before she joins on another, because the threads near the end have not above a quarter of their full thickness. The cocoons produce a very unequal length; some may be met with which yield 1200 ells, whilst others will scarcely afford 200 ells. In general, the production of a cocoon may be estimated from 500 to 600 ells in length. As often as the cocoons she winds are exhausted, or break, or only diminish, she joins fresh ones to keep up the requisite number, or the proportion; because, as the cocoons wind off, and the thread becomes finer, she must join two cocoons half wound to replace a new one. Thus she can wind three new ones and two half wound, and the silk will be equal to that produced from four to five cocoons. When she would join a fresh thread she must lay one end on her finger, throw it lightly on the other threads which are winding, and the gum will join it immediately, and it will continue to go up with the rest. She must not wind off her cocoons to the last, because when they are near at an end the husk of the worm joins in with the other threads, and makes the silk foul and gouty. The silk may be wound of any size from one cocoon to 100, but it is difficult to wind more than thirty in a thread.

The nicety of the operation, and that part in which lies the greatest difficulty, is to wind an even thread, because as the cocoon winds off the end is finer, and other cocoons must be joined on to keep up the same size. This difficulty

of keeping the silk always even is so great, that (excepting a thread of two cocoons, which is called *fuch*) they do not lay a silk of three, four, or six cocoons; but a silk of three to four, four to five, or six to seven cocoons. In a coarser silk it cannot be calculated even so nearly as to four cocoons more or less; they say, for example, from 12 to 15, from 15 to 20, and so on.

During the operation of winding, the woman must always have a bowl of cold water by her, to dip her fingers in, and to sprinkle frequently upon the iron bar *c*, that the heat of the basin may not burn the threads, also to cool her fingers every time she dips them in the hot water, and to pour into the basin when necessary, that is, when the water begins to boil. The water must be just in a proper degree of heat; for when it is too hot, the thread is dead, and has no body; and when too cold, the ends which form the thread do not join well, and form a harsh silk. The heat of the water from which the cocoons are wound, causes that adhesion of the fibres which compose the silk: a thread can with difficulty be wound off when cold water is employed; but in this manner the adhesion is very slight, and the thread breaks with a slight force, or the least moisture will separate the fibres; but the silk wound from hot water cannot be separated except by hot water.

The old cocoons require the water to be very hot: if the threads break very frequently, it may be concluded that the water is too cold; or, on the other hand, if the silk comes off entangled, and in the state of wool, the water is too hot. When the first parcel of cocoons is finished, the basin, A, is cleaned, taking out all the striped worms, as well as the cocoons, on which there remains a little silk: these are thrown into a basket, into which the loose silk that comes off in making the battue is likewise put as waste silk, to be carded and spun into threads. The water in the basin must be changed four times a day for coarse silk, and twice only for good cocoons of fine silk: if the water is not changed, the silk will not be so bright and glossy, because the worms contained in the cocoons foul it very considerably. The reeler must endeavour to wind as much as possible with clear water, for if there are too many worms in it, the silk will be covered with a kind of dust, which afterwards attracts moths, which destroys the silk.

From the gummy or viscid material which silk gives out to water when the cocoons are infused in it, Chappe found that he was able to blow up the water into bubbles, or small balloons, far more permanent than those of soap and water, and offering all the colours of the rainbow. So close, indeed, is the texture of these silky bladders, that even the most subtle gas does not penetrate them. Chappe filled many of them, the diameter of each not exceeding three inches, with hydrogen gas, and found several of them continued in a state of suspension, in an apartment, for considerably more than twenty-four hours. It is not all silk, however, that is sufficiently glutinous for this purpose; that which is of a very deep yellow will not answer the same purpose. This silk, from its colour, is supposed to be produced by the worm in a peculiar disease, yet this is a state by no means uncommon.

All kind of silk which is simply drawn from the cocoons by the reeling, is called raw silk, but is denominated fine or coarse according to the number of fibres of which the thread is composed. In general, the raw silk requires dyeing; to prepare for which the thread is very slightly twisted, to render it strong, and more able to bear the action of the hot liquor, without separating the fibres or furring up. Silk-yarn, which is employed by the weavers for the woof or weft of the stuffs which they fabricate, is composed of

two or more threads of the raw silk, slightly twisted in a machine; and the thread employed by the stocking weaver is of the same quality, but composed of a greater number of threads, according to the thickness desired. Organzine silk is composed of two, three, or four threads of raw silk twisted, and so combined as to obtain the greatest strength: for this purpose, each thread of raw silk is twisted separately upon itself by a mill: the twist is given in a right-handed direction, and extremely tight. By a second operation of twisting, two of these threads are combined together, the twist being given in a contrary direction, and not above half as tight: this forms a thread similar to a rope. This description of silk, used for the warp of stuffs, is of the utmost importance to the manufacturer, for none of the principal articles can be fabricated without it. The Italians, from whom we formerly imported the silk in the state of organzine, for a long time kept the art of throwing it a profound secret. It was introduced into this country by the enterprise and skill of Messrs. Thomas and John Lombe, the latter having, at the risk of his life, and with wonderful ingenuity, taken a plan of one of these

secret machines in the king of Sardinia's dominions, from which, on his return, they established a similar set of mills in the town of Derby. (See DERBY.) In consideration of the great hazard and expence attending the undertaking, a patent was granted to Sir Thomas Lombe in 1718, for securing to him the privilege of working organzine for the term of fourteen years; but the construction of buildings and engines, and the instruction of the workmen, took up so much time, that the fourteen years were nearly expired before he could derive any advantage from it; in consequence of which, he petitioned parliament, in 1731, to grant him a further term: but parliament, considering it an object of national importance, granted him the sum of 14,000*l.* on condition that he should allow a perfect model of the machinery to be taken, and deposited in the Tower of London for public inspection. Similar mills were, in course of time, erected in different parts of the country; but owing to the difficulties that were experienced in procuring raw Italian silk of the proper size for organzine (the exportation of which was prohibited by the Italians), and to the mills having subsequently found employment for other purposes, the quantities worked into organzine, for many years, bore scarcely any proportion to the imports from Italy; it has however been since revived and improved, in consequence of which it is now carried on to a very considerable extent, as well in other parts of England as at Derby.

The process which the silk undergoes to bring it into this state, consists of six different operations. 1. The silk is wound from the skein upon bobbins in the winding machines. 2. It is then sorted into different qualities. 3. It is spun or twisted on a mill in the single thread, the twist being in the direction of from right to left, and very tight. 4. Two or more threads thus spun are doubled or drawn together through the fingers of a woman, who at the same time cleans them, by taking out the slubs which may have been left in the silk by the negligence of the foreign reeler. 5. It is then thrown by a mill, that is, the two threads are twisted together, either slack or hard, as the manufacture may require; but the twist is in an opposite direction to the first twist, and it is wound at the same time in skeins upon a reel. 6. The skeins are sorted according to their different degrees of fineness, and then the process is complete.

The first operation which the raw silk undergoes is winding, that is, drawing it off from the skeins in which it is imported, and winding it upon wooden bobbins, in which

state it can go to the other machines. The winding-frame is shewn at *fig. 2.* of the plate, or rather a part of it, which will wind six threads at once, and by increasing the length it may be made to receive any number. Each of the skeins is extended upon a slight reel *AA*, called a swift; it is composed of four small rods, fixed into an axis, and small bands of string are stretched between the arms to receive the skein, but at the same time the bands admit of sliding to a greater or less distance from the centre, so as to increase the effective diameter of the reel, according to the size of the skein, because the skeins, which come from different countries, vary in size, being generally an exact yard, or other similar measure, of the country where the silks are produced. The swifts are supported upon wire pivots, upon which they turn freely when the silk is drawn off from them; but in order to cause the thread to draw with a gentle force, a looped piece of string, or wire, is hung upon the axis within the reel, and a small leaden weight, *c*, being attached to it will cause a sufficient friction. *B, B,* are the bobbins which draw off the threads; they are received in the frame, and are turned by means of a wheel beneath each, the bobbin having a small roller upon the end of it, which bears by its weight upon the circumference of the wheel, and the bobbin is thereby put in motion to draw off the silk from the swift. *D* is the layer, a small light rod of wood, which has a wire-eye fixed into it, opposite to each bobbin, so as to conduct the thread thereupon; and as the layer moves constantly backwards and forwards, the thread is regularly spread upon the length of the bobbin. The motion of the layer is produced by a crank fixed upon the end of a cross-spindle, *E*, which is turned by means of a pair of bevelled wheels from the end of the horizontal axle, upon which the wheels for turning all the bobbins are fixed.

These winding-machines are usually situated in the top building of the mill, the frames being made of great length, and also double, to contain a row of bobbins and swifts at the back as well as in front. Two of these double frames are put in motion by cog-wheels from the vertical shaft, *F*, which ascends from the lower apartments of the mill, where the twisting-machines are placed. The winding-machines require a constant attendance of children to mend the ends or threads which are broken; or when they are exhausted, they replace them by putting new skeins upon the swifts. When the bobbins are filled they are taken away, by only lifting them up out of their frame, and fresh ones are put in their places.

A patent has been lately taken out by Messrs. Gent and Clarke, for a new construction of the swifts for winding-machines: they are made with six single arms instead of four double ones; and the arms are small flat tubes, made to contain the stems of wire forks, which receive the skein instead of the bands of string in the common swifts. These forks admit of drawing out from the tubes until the swift is sufficiently enlarged to extend it; but as they extend the skein at six points instead of four, as in the common one, the motion is more regular. Instead of the weight which causes the friction, a spring is used to press upon the end pivot of the axis, and make the requisite resistance.

The twisting of the silk is always performed by a spindle and bobbin, with a flyer, but the construction of the machine which puts the spindle in motion is frequently varied. The limits of our plate do not admit a representation of the great machines, or throwing-mills, such as are used at Derby, and at almost all the other great silk-mills in England. In *fig. 3.* we have given a drawing of a small machine, which is similar in the parts which act upon the silk; and indeed many mills employ such machines constructed on a large scale.

The one in our plate contains only thirteen spindles, and is intended to be turned by hand, a method which is too expensive for this country, but is common in the south of France, where many artisans purchase their silk in the raw state, and employ their wives or children to prepare it by these machines, which they call ovals, because the spindles *b, b*, are arranged in an oval frame, *G H*. *B* is the handle by which the motion is given; it is fixed on the end of a spindle, *R*, which carries a wheel, *D*, to give motion to a pinion upon the upper end of a vertical axle, *E*: this, at the lower end, has a drum or wheel *F*, to receive an endless strap or band, *a a*, which encompasses the oval frame *G*, and gives motion to all the spindles at once. The spindles *b, b*, are placed perpendicularly in the frame *G H*, their points resting in small holes in pieces of glass, which are let into the oval plank *G*; and the spindles are also received in collars affixed to an oval frame *H*, which is supported from the plank, *G*, by blocks of wood; *d* and *a* are small rollers, supported in the frame *G H*, in a similar manner to the spindles: their use is to confine the strap, *a*, to press against the rollers of the spindles with sufficient force to keep them all in motion.

The thread is taken up as fast as it is twisted by a reel, *K*, which is turned by a wheel, *b*, and a pinion, *i*, upon the end of the principal spindle, *R*. The threads are guided by passing through wire-eyes, fixed in an oval frame, *L*, which is supported in the frame of the machine by a single bar or rail, *l l*, and this has a regular traversing motion backwards and forwards, by means of a crank, or excentric pin, *t*, fixed in a small cog-wheel, which is turned by a pinion upon the vertical axis *E*; the opposite end of the rail, *l*, is supported upon a roller, to make it move easily. By this means the guides are in constant motion, and lay the threads regularly upon the reel *K*, when it turns round, and gathers up the silk upon it, as shewn in the figure.

One of the spindles is shewn at *r* without a bobbin, but all the others are represented as being mounted and in action. A bobbin, *e*, is fitted upon each spindle, by the hole through it being adapted to the conical form of the spindle, but in such manner, that the bobbin is at liberty to turn freely round upon the spindle: a piece of hard wood is stuck fast upon each spindle, just above the bobbin, and has a small pin entering into a hole in the top of the spindle, so as to oblige it to revolve with the spindle; this piece of wood has the wire-flyer, *b*, fixed to it: the flyer is formed into eyes at the two extremities; one is turned down, so as to stand opposite the middle of the bobbin *e*; and the other arm, *b*, is bent upwards, so that the eye is exactly over the centre of the spindle, and at a height of some inches above the top of the spindle. The thread from the bobbin, *e*, is passed through both the eyes of this wire, and must evidently receive a twist when the spindle is turned; and at the same time, by drawing up the thread through the upper eye, *b*, of the flyer, it will turn the bobbin round and unwind therefrom. The rate at which the thread is drawn off from the bobbin, compared with the number of revolutions which the flyers make in the same time, determines the twist to be hard or soft; and this circumstance is regulated by the proportion of the wheel, *b*, to the pinion *i*, from which it receives motion; and these can be changed when it is required to spin different kinds of silk. The operation of the machine is very simple; the bobbins filled with silk in the winding-machine, *fig. 1*, are put loose upon the spindles at *e*, and the flyers are stuck fast upon the top of the spindles: the threads are conducted through the eyes of the flyers *b*, and of the layers *L*, and are then made fast to the reel *K*, upon which it will be seen that there are double the number of skeins to that of the spindles represented, because

one half of the number of the spindles is on the opposite side of the oval frame, so that they are hidden. With this preparation the machine is put in motion, and continues to spin the threads by the motion of the flyers, and to draw them off gradually from the bobbins, until the skeins upon the reel are made up to the requisite lengths. This is known by a train of wheel-work at *n o p*, consisting of a pinion, *n*, fixed upon the principal spindle *R*, turning a wheel *o*, which has a pinion fixed to it, and turning a larger wheel *p*; this has another wheel upon its spindle, with a pin fixed in it, which at every revolution raises a hammer, and strikes upon a bell, *s*, to inform the attendant that the skeins are made up to a proper length. When this machine is employed for the first operation of twisting the organzine, the wheel, *b*, must be larger, and the pinion, *i*, smaller than represented, in order that the reel, *K*, may be turned slowly, and the threads will therefore receive a stronger and closer twist. Also, the handle *B* is turned in an opposite direction to that in which it must move for the final throwing off the two or three twisted threads together; and as it must also move for twisting the raw threads together for the warp of silk-stuffs, and for weaving stockings, this reverse movement makes no alteration in the machine, except that it will give twist in a contrary direction; for it is always necessary, when two or more twisted threads are combined by twisting, that the twist of the original threads shall be in the opposite direction to that twist which unites them into one thread, in the same manner as for making ropes, organzine silk being in fact small rope, and stocking-silk or warp being only yarn. The silk which is intended to be dyed, is previously twisted very slightly in this machine, and of course in that direction which will suit the purpose for which it is ultimately intended; *viz.* whether for yarn or organzine.

The great mills for twisting silk, originally introduced by Messrs. Lombe, though very complicated, are simple in their operation, because the complexity arises from the great number of spindles which are actuated by the same movement, every one of which produces its effect independent of the others, and in the same manner as the oval which we have described. A machine is contained in a circular frame, of which the diameter varies from 11 to 13, 15, and even 17 feet; but 15 feet is the general size of the original Piedmontese machines. In the centre of the frame is a perpendicular axis or spindle, coming up through the floor of the chamber, and rising to the ceiling; it is put in motion by a communication of wheel-work from a water-wheel, or otherwise from a horse-wheel. The axis has upon it two, three, or four horizontal wheels, according to the height of the machine, which revolve with it, and are of a sufficient size to fill nearly all the interior of the circular frame, and act upon the pulleys or rollers of the spindles, which are supported vertically in the frame, and arranged round the machine, at equal distances, in a circle, the number being proportioned to the dimensions of the machine. The spindles are also arranged in as many different stages of height as there are wheels upon the vertical spindle; for the circumference of each wheel presses against the rollers of the spindles which are arranged round it; and thus, when the wheel revolves, it gives a very rapid motion to all the spindles at once, by the contact of the edge of the wheel, but without any strap, as in the oval. Each spindle has a bobbin, filled with silk, fitted upon the top of it, and from this the silk is carried up to a horizontal reel, which is turned round slowly by the machine, and draws off the thread gradually from the bobbin: the flyer, being all the while in rapid motion, twists the thread upon itself, or, if two or three threads are previously wound together upon the bobbin, they will be

twisted round each other. Each reel serves to take up the thread from several spindles which are situated beneath it : thus, in a mill of fifteen feet diameter, there will be six spindles beneath each reel.

To explain this machine more clearly, we will give a description of one of thirteen feet diameter, which has four large wheels and stages of spindles, two of which are for giving the first preparation to the organzine : the spindles revolve in a direction from right to left. The spindles of the other two stages are for the finishing the twist, and also for twisting the single threads which are to be used for warp or for stocking-weaving : they revolve in a contrary direction to the former. The frame of the machine consists of two wooden circles of thirteen feet diameter, one placed upon the floor of the mill, and the other at a height of fifteen feet above, the two being united by fourteen upright pillars of wood, which altogether compose a large cylindrical frame or lantern. Each stage contains eighty-four iron spindles, placed vertically, and supported in the stage, which is formed of two wooden circles, extended round between the fourteen uprights of the lantern, and fixed one above the other, at about a distance of four inches asunder, so as to support the spindles between them, in the same manner as the pieces, G, H, of the oval last described.

The circles of the stage are of a rather less diameter than the two circles which compose the top and bottom of the lantern ; so that the spindles will be rather within the circle of the frame of the lantern, and admit the wheels of the central axis to act upon them. For this purpose, each of the circles of the stage is made up by fourteen segments fixed between the uprights, and each segment supports six spindles, making up the number of eighty-four in the whole circle. The spindles, like those of the oval, are sharp-pointed at the lower end, and the points rest in small holes made in pieces of glass, which are let into the lower circle of the stage, whilst the upper circle sustains the spindle at a height of four or five inches above the point, leaving full one-third of the length of the spindle projecting above, for the purpose of fitting the bobbin upon it. The upper circle of the stage is rather smaller than the lower, because the spindles do not pass through it, but through holes in small pieces of hard wood, which project from it, so as to be exactly above the pieces of glass which sustain the points of the spindles. Each spindle has a small roller fixed upon it in the space between the two circles of the stage, and it is the contact of the rim of the great wheel upon these that causes the revolution of the spindles when the wheel revolves. In order to make the contact certain, the exterior rim of the great central wheel is made in several segments, and each segment has a constant tendency to recede from the central axis by the action of a weight, and thus press against the rollers of the spindles. In order to give the reverse movement of the spindles, which we have before spoken of in the description of the oval, the great wheels for two of the stages are made differently from those which we have just described, so that the segments of the rim will act upon the outsides of the rollers of the spindles, instead of the insides : for this purpose the wheels are made larger than the stages in which the spindles are placed, and from the rim of the wheel small pillars rise up to support the segments, which act upon the rollers of the spindles in front or withoutside of the circles, instead of the inside, as is the case with the other stages, in consequence of which the spindles of these stages turn in opposite directions. The reels are placed over the bobbins, to take up the threads when twisted ; and the rollers of the different spindles are made smaller or larger, as is required, to give more or less twist to the silk

operated upon by them ; for the velocity with which the spindles revolve, compared with the rate at which the reels take up the thread, determines the degree of twist which the thread will have ; and to render this equable, the reels which draw off the silk from the bobbins of the spindles are turned regularly with the motion of the machine by means of wheel-work, which is more easily conceived than described : it is sufficient to state that it receives its motion from the central vertical axis. There is also a layer adapted to each reel, with a wire-eye to receive each thread ; and the layers having a slowly reciprocating motion, distribute the threads regularly upon the reels, in a similar manner to that first described for the oval. One of these reels is placed between each of the uprights of the machine, so as to make fourteen reels in the whole circle of each stage, and every reel serves to take the silk from the bobbins of six spindles. The whole machine in the four stages contains 336 spindles.

A machine of four stages is so high, as to reach through two floors of the mill, and for this purpose the upper floor is made with a large round opening, to admit the machine : this floor serves the people who attend the machine, and change the bobbins when exhausted, and also remove the finished silk from the reels.

The spindles in the upper stages are usually devoted to the first twisting of the single threads for the organzine, and therefore turn the reverse way, as before mentioned ; and as the silk is afterwards to be thrown, or re-twisted, they are drawn off from the bobbins by large bobbins of three inches diameter, and four inches long, instead of the reels. These bobbins are stuck six together upon a long spindle, situated horizontally, and turned by similar wheel-work to that which actuated the reels ; they have similar layers to conduct the silk regularly upon the bobbins from one end to the other, so that the operation is not at all different.

In many of the best silk-mills, they have abandoned the original method of turning the spindles, for the preparation of organzine, the reverse way, by making the action of the wheels upon the outside, instead of the inside, of the circle of spindles. Instead of them they employ two different machines, one for the first operation on organzine, and the other for the second operation, both of them constructed with the wheels withinside : but the motion of the two machines is reversed to each other.

Fig. 5. represents a single spindle of a throwing machine, which, though the same in its action as the great mill, is different in its construction. G and H represent portions of the rails or circles of the stage which support the spindle, and *aa* is a part of the rim of the great wheel of the central axle. This wheel is not made in segments, as before described, but is made very truly circular, and covered with leather on the edge, that it may act with more force to turn the roller, *t*, of the spindle. The point of the spindle rests in a glass cap, supported by the rail G, and the roller, *t*, is always made to press against the rim of the great wheel, *aa*, by a small lever, *d*, and a string, which, after turning over a pulley, has the weight, *c*, made fast to it, to press the spindle always towards the wheel. In this machine, instead of the reel, the thread is taken up by a bobbin, K, is put into a frame, *m*, which moves on pivots, and by a weight, *n*, is pressed down so as to make the bobbin bear upon the edge of a wheel, *b*, which is kept in constant and regular motion, by the same kind of movement which turns the reels of the great machine. The intention of this is, that the action of the wheel, *b*, to turn the bobbin, being communicated by pressure against the part upon which the silk is to wind, will be con-

stant, and will not draw more when the bobbin is large and full, or less when it is empty, as must be the case when the motion is given to the axis of the bobbin.

After the silk is twisted in a right-hand direction, if it is intended for yarn, or for dyeing; or in a left-hand direction, if it is prepared for organizing; it must be wound on fresh bobbins, with two or three threads together, preparatory to twisting them into one thread. In the original machines at Derby this was done by women, who, with hand-wheels, wound the threads from two or three of the large bobbins, upon which the silk is gathered instead of the reels, and assembled them two or three together upon another bobbin, of a proper size to be returned to the twisting mill. We have seen an attempt for a machine to perform the doubling, which is slightly represented in *fig. 4*. The whole machine itself is very similar to the winding-machine, *fig. 2*, but instead of the twist, the bobbins from the throwing-mill are placed in front at *A*, *fig. 4*, two or three in a row. The threads from these are pulled over the rail *m*, and beneath a piece of wood, *n*, both which, being covered with cloth, have the same effect to clean the silk by drawing through them, as the fingers of the winder. *B* is the bobbin upon which the two or three threads are to be wound together; it is turned by a wheel, *F*, upon which it rests, the same as the bobbins of the winding-machine; and *D* is the layer, which, for convenience, is in this case placed behind the bobbin, *B*; and the wire-eye, *d*, which receives the three threads, is made to reach over to the front. The additional apparatus consists of a small piece of wood, *e*, which slides freely up and down, in a hole, through a fixed board, *f*. On the top of the slider, *e*, is an eye of wire, through which one of the single threads of silk passes in its passage from between the pieces *m*, *n*, to the bobbin *B*: there is one of these sliders, *e*, to each of the three threads; *tv* is a lever moving on the centre *w*; the end *t* is immediately beneath the small sliders *e*, and the end *v* is formed to a hook, to catch into the notches which are made in the end of the bobbin *B*. A small counter weight, *x*, always causes the hook, *v*, of this lever to recede from the bobbin; but if any one of the three threads break, it suffers the slider *e*, which belongs to it, to descend upon the end, *t*, of the lever, and depresses the end of the lever, so as to bring the hook, *v*, in a situation to catch a tooth of the bobbin *B*, and stop its motion. By this means the winding of three threads together is rendered equally certain with the winding of one; for when any one breaks, the operation of winding on that bobbin stops, until the attendant repairs the broken thread, and puts the machine again in motion. We have lately been informed, that a machine for winding two and three threads together is becoming common in the silk-mills, but we do not know if it is the same with this one, which however is not evidently impracticable.

The bobbins, being thus filled with double or triple threads, are carried back to the throwing machine, and are there spun or twisted together, the manner of doing which does not differ from the operation which we have before described. In this second operation the silk is taken up by reels instead of bobbins, and is thus made up into skeins. The degree of twist varies with the purpose for which the silk is intended; and the wheels which give motion to the reels are for this purpose adapted to the degree of twist which the silk is desired to have. The silk, being now spun, requires only the preparation of boiling to discharge the gum, and render the silk fit to receive the dye, and also to render it soft and glossy. The silk is boiled for about four hours, in a boiler filled with water, into which a small quantity of soap is put; this opera-

tion dissolves the gum, which before could be felt upon the silk, and rendered it harsh. After the boiling, it is well washed in a current of clear water, and when dried, will be found to have lost about one-fourth of its weight: at the same time the volume of the silk is sensibly increased, and it has acquired that soft texture and glossiness, which are the principal beauties of silk. This change is produced by the dissolution of the gum, which, in the first instance, was the only adherence of the fibre to form a thread, but by the operation of the twisting the fibres are firmly united, and no longer require the gum. It is also necessary, in order to give a fine dye to the silk, that the gum should be removed, because it would prevent the entrance of the dyeing matter to the centre of the thread, and thus impair the beauty of the colour. If the silk was thus boiled before the twisting, nothing but a fine entangled down or wool would be obtained, and it would require spinning, by a similar process to that of cotton, before a thread could be obtained. This, indeed, is necessary for that portion of waste silk which is drawn from the cocoons in the first operation of reeling; also for those cocoons which are reserved for breeding, and from which the moths eat their way out by holes, which render it impracticable to wind off the silk. This waste silk, when carefully spun by a spinning-wheel, is called spun silk, and the thread is not inferior to the regular silk which is wound off: indeed, the winding off the silk into a thread united by its gum, is of no advantage farther than as a preparation for spinning, from which process the thread obtains its strength.

The silk is now in a state for use: if it is for stocking-weaving, or sewing, or if intended for weaving into stuff, it only requires warping to be put into the loom. The operation of warping is to put together all the threads which are to compose the warp of the intended piece of stuff, and lay them parallel, so that the warp, being put into the loom, will have no slack threads, nor any which are strained too tight. Formerly, this operation was performed by stretching the threads out at length in a field, or by extending them in a frame, and winding them backwards and forwards over pegs. The warping machine now universally employed is shown in *fig. 6*, where *AA* is a tressel or stool, which supports the small bobbins *b, b*, upon which the silk is wound. The number of these is equal to the number of threads which the warp of the intended piece of stuff is to have in its breadth. The threads from all these bobbins are drawn over wires *d, d*, which are in front of the bobbins, and are then all brought together, and passed through an opening in a piece of wood *D*; this conducts the threads all together upon a large reel *EE*, which is supported in a frame *FFF*, and turned round by means of a pulley at the lower end of its axle, from which an endless band is continued to a second wheel *G*, mounted on a spindle, and turned by a handle. This latter spindle is supported in a sort of stool *H*, upon which a child sits down, and at the same time turns the handle and puts the reel in motion, so as to draw the warp or assemblage of threads off from the several bobbins, and lay it upon the reel *E*. The piece of wood *D* is fitted upon one of the upright pieces, *F*, of the frame, to slide freely up and down upon it, and is suspended by a cord, which, after passing over a pulley *f*, is wrapped round the spindle of the machine at *c*: by this means, the motion of the reel, *E*, draws the cord, and raises up the piece *D*, so as to lay the warp upon the circumference of the reel, in a regular spiral, from one end to the other, and prevent the coils lapping one upon another. When the required length of warp is wound upon the reel, the ends of all the threads are cut off, tied together, and thus drawn off from the reel and rolled up into a large ball,

in which state the weaver takes it, and mounts it in his loom.

For the subsequent operations of weaving we shall refer to the article *WEAVING*, because the weaving of silk goods is the same as for any other, except that finer and more beautiful articles are produced in this substance than in any other. Some information on the details of weaving mechanism will be found under our articles *DRAUGHT OF LOOMS*, *DRAW-LOOM*, *DIAPER*, *DIMITY*, and *DORNOCK*; and though these are rather the weaving of linen and cotton than silk, the same principles apply to silk, as will be more fully explained under *WEAVING*; where a description of weaving ribbands and figured silks will be given.

Silk is distinguished by different names according to its different states. Thus,

SILK, Spun, is that taken from the ball, without fire, and spun into thread without any coction: such as is most, if not all, that is brought into England from the Levant; *i. e.* from Persia by the way of Turkey, from Bengal in India, and from China. The raw spun silk is commonly worked up into two sorts, called *organize* and *tram*: the former is made by giving a throw or twist to each thread of raw spun silk singly, and then doubling two of these twisted threads together, and twisting them smartly together; this forms the warp or length of a piece when manufactured. The tram, or shoot, which makes the breadth of the piece, is formed by twisting two or more threads of raw silk slack. The waste raw silk, or refuse in reeling, &c. is collected, carded, and spun, and called *fosse* silk; this is doubled and thrown, and often made into a cheap sort of silk-stockings, which are very strong and durable.

In the French silk-works, the greatest part of this raw silk passes for little better than a kind of fine florette; yet, when spun, it makes a bright thread, and serves for the manufacture of stuffs of moderate value and lustre. But the spun silks of the Levant, whence most of our's come, are exceedingly fine and beautiful. The difference arises hence, that in France, the best balls are reeled off in boiling water, and only the refuse made into spun silk; whereas, in the Levant, there is no such thing as reeling or winding on the fire, but the silks are all sent in bales, or packs, as they are drawn from off the balls; so that they are only distinguished by their quality of fine, middling, and coarse.

SILK, Boiled, is that which has been boiled in water, to facilitate the spinning and winding. This is the finest of all the sorts of silk manufactured in France, and is seldom used but in the richest stuffs; as velvets, tasseties, damasks, brocades, &c.

There is also another kind of boiled silk, which is prepared by boiling, to be milled; and which cannot receive that preparation, without being first passed through hot water. By the laws of France, it has been prohibited to mix raw with boiled silk; both as such a practice spoils the dyeing, and as the raw silk corrupts and cuts the boiled.

SILKS, thrown or twisted, are such as, besides their spinning and winding, have received their milling or throwing.

This they receive in a different degree, as they are passed oftener or seldomer over the mill; properly, however, thrown silks are those in which the threads are pretty thick-thrown, and twisted several times.

The thrown silk comes to us chiefly from Leghorn, Genoa, Naples, and Messina.

SILKS, Slack, are such as are not twisted, but are prepared, and dyed for tapestry, and other works with the needle.

SILK, Eastern or East Indian. That popularly thus called is not the work of the silk-worm, but comes from a plant that produces it, in pods, much like those of the cotton-

tree. The matter this pod contains is extremely white, fine, and moderately glossy; it spins easily, and is made into a kind of silk, that enters the manufacture of several Indian and Chinese stuffs.

SILKS, French. It is only in the most southern provinces of France that silk is cultivated, mulberry-trees planted, and worms bred. The principal places are Languedoc, Dauphiné, Provence, Avignon, Savoy, and Lyons. This last place, indeed, furnishes very few silks of its own growth; but it is the great staple whence the merchants of Paris, and the other cities, are to fetch them. At least, they are obliged to have them pass through Lyons, if they bring them from other places, either by land or sea. There have been computed to enter Lyons, *communibus annis*, six thousand bales; the bale valued at one hundred and sixty pounds weight; of which six thousand bales, there are one thousand four hundred from the Levant, one thousand six hundred from Sicily, one thousand five hundred from Italy, three hundred from Spain, and one thousand two hundred from Languedoc, Provence, and Dauphiné.

At the time when the manufactures of Lyons were in their prosperity, there were reckoned to be eighteen thousand looms employed in the silk manufacture; but in 1698, there were not reckoned four thousand. However, this manufacture afterwards revived, and a great part of Europe has been supplied from hence with brocade and rich silks. The decay has not been less notable at Tours; they had formerly there eight hundred mills for winding and preparing the silks; eight thousand looms to weave them; and forty thousand persons employed in the preparation and manufacturing of them; but these have been reduced to seventy mills, twelve hundred looms, and about four thousand persons. The revolution has, however, made such an alteration in the manufactures and trade of France, and they are still (1816) in so unsettled a state, that no correct estimate of them can be obtained.

SILKS, Sicilian. The commerce of the silks of Sicily has been very considerable; and the Florentines, Genoese, and Luccefe, are the people who have chiefly availed themselves of it. Great quantities were yearly brought thence, especially from Messina; part of which they used in their own manufactures, and sold the rest to their neighbours the French, &c. with profit. The Italians had this advantage, especially the Genoese, over other people, that, having large establishments in the island, they were reputed as natives, and paid no duty for the export.

Part of the Sicilian silks is raw, the rest are spun and milled; of which last kind, those of St. Lucia and Messina are the most valued. The raw unwrought silks were always sold for ready money; the others, sometimes, in exchange for other goods. See SICILY.

SILKS, Italian. The silks brought from Italy are partly wrought, and partly raw and unwrought. Milan, Parma, Lucca, and Modena, furnish none but the latter kind; Genoa most of the former; Bologna affords both kinds. The finest Italian wrought silk comes from Piedmont, Novi, Bergamo, and Bologna; and is imported into England from the ports of Nice, Genoa, and Leghorn.

The silk we have from Italy is generally thrown, and serves for warp for our manufactures.

SILKS, Spanish, are all raw; and are spun, milled, &c. in England, according to the several works in which they are to be used.

SILKS, Turkey, are all raw. One advantage we have in the commerce of the Levant, in silks, wanting in those of Sicily, is, that the latter are confined to a particular season of the year; whereas the former are bought at all times.

They are brought from Aleppo, Tripoli, Sayda, and from the isle of Cyprus, Candia, &c. But the principal place of commerce, especially for the silks of Persia, is Smyrna. The silks are brought hither in caravans, from the month of January to September. The caravans in January are laden with the finest silks; those of February and March being indifferent ones; the rest, the coarsest. They all come from the several provinces of Persia, chiefly those of Ghilan and Shirvan, and the city of Schamachia, situate near the edge of the Caspian sea; from which three places, a Dutch author assures us, there have not come less than thirty thousand bales of silk in a year. Ghilan produces the best and greatest quantities of silk; next to this are Shirvan and Erivan, then Mazanderan, and lastly Astrabad; but the latter is much inferior, serving only for a manufacture mixed with cotton; that of Mazanderan and Astrabad is seldom or ever exported.

Ardeuil, or Ardebil, another city of Persia, not far distant from these silk countries, is the place where silks are laid up, and whence the caravans set out for Smyrna, Aleppo, Scanderoon, and Constantinople; and it is this city, with Schamachia, that have always been esteemed the centre of the silk trade; which has been several times attempted to be removed from Smyrna, and the Mediterranean, in favour of Archangel, and the White sea, by carrying them across Muscovy, by the Volga and Dwina, two rivers that traverse the principal provinces of that vast empire.

This new course of the Persian silks into Europe was first proposed by Paolo Centurio, a Genoese, to the czar Basil, under the pontificate of Leo X. The French had the same design in 1628. The duke of Holstein, in 1633, sent ambassadors to the court of Persia, purely with the same view. And in 1668, the czar Alexis Michael attempted the thing himself; but he was disappointed by the rebellion of the Cossacks, and the surprise of Astrakhan.

In 1688, the commerce of Persian silks had nearly been removed from Smyrna by an earthquake, which almost overturned the whole city; and, doubtless, the removal had been effected, but for the vigorous means used by the Turks to prevent it. Smyrna, however, still remains in her ancient possession; and the several nations of Europe continue every year to send their fleets, to fetch away the silks.

SILKS, China, Japan, and Indian. Several provinces of China are so fertile in mulberry-trees, and their climate is so agreeable to the nature of silk-worms, that the quantity of silks there produced is incredible; the single province of Tchehiang might supply all China, and even a great part of Europe, with this commodity. The silks of this province are the most esteemed, though those of Nankin and China be excellent.

The silk-trade is the principal in China, and that which employs the most hands; but the European merchants who deal in it, especially in wrought silks, are to be careful of the spinning, &c. the waste being usually very great, as the French East India company have found to their cost.

Japan would not afford fewer silks than China; but that the Japanese, a barbarous and distrustful people, have interdicted all commerce with strangers, especially with Europeans, excepting with the Dutch; who are said to be admitted on certain impious terms, related by Tavernier, but which, we must own, we cannot credit. The Dutch have endeavoured to vindicate themselves from these by the pens of several famous writers.

Great quantities of both raw and wrought silk are furnished by other parts of Bengal, and by several provinces of

Hindooistan, which partly supply the natives, and afford a very considerable exportation to Europe. Several thousand bales of raw silk are annually imported from Bengal and China; some of which is, in this state, used for making princes' stuffs, but the greater part is prepared for the manufacturers by the silk-throwsters.

SILK, Laws relating to. The duties on silks and calicoes being under the same regulations with those on printed linens, the law respecting them is inserted under the article **LINEN**. By the 13 & 14 Car. II. c. 15. s. 2. no person shall exercise the trade of a silk-throwster, unless he hath served seven years' apprenticeship, on pain of 40s. a month, half to the king, and half to him that shall sue in any court of record, or at the assizes, or quarter-sessions of the peace. By 9 & 10 W. c. 43. no foreign silks, called alamodes or lutestrings, shall be imported but in the port of London, on notice first given to the commissioners of the customs, and licence had from them, on pain of forfeiture, or the value; and they shall be sold, and exported again; and the offender for importing, and also the receiver and person offering to sell the same, shall forfeit 500*l*. Being marked and sealed by order of the commissioners, any person who shall counterfeit the custom-house seal, or that of the lutestring company, shall forfeit 500*l*., and be set in the pillory for two hours. And any person who shall buy and sell, and have in his custody, any alamodes or lutestrings, sealed or marked with a counterfeit seal or mark, shall forfeit the same and 100*l*.

However, none but custom-house officers, or persons deputed by the lutestring company, and having writs of assistance under the seal of the exchequer, shall seize lutestrings or alamodes within the bills of mortality. (5 Ann. c. 20.) The penalties shall be two-thirds to the king, and one-third to him that shall seize or sue in any court of record.

By 3 Geo. III. c. 21. and 5 Geo. III. c. 48. if any person shall import any ribbands, laces, or girdles, not made in Great Britain, whether the same shall be wrought of silk alone, or mixed with other materials, the same shall be forfeited, and may be seized by any officer of the customs, in whatever importers', venders', or retailers' hands they may be found; and the importer, and every person assisting therein, and the venders and retailers in whose custody they shall be found, or who shall sell or expose the same to sale, or conceal with intent to prevent the forfeiture, shall forfeit respectively 200*l*., with costs. Half the said penalties to be to the king, and half to the officer who shall inform and prosecute.

But if any officer of the customs shall neglect or refuse, for one month after condemnation, to prosecute to effect any person for any of the said pecuniary forfeitures, any other person may sue for and recover the same; half thereof to go to the king in like manner, and half to him who shall sue.

And when the goods seized (being out of the limits of the bills of mortality) shall not exceed the value of 20*l*., two justices, on information before them that such goods were seized, as unduly imported, may hear and determine the same, and proceed to condemnation or discharge.

After seizure, until condemnation or discharge, the said goods shall be deposited in one of the king's warehouses, if the seizure be within the bills of mortality; elsewhere, in the hands of the chief magistrate or constable; and the same shall be free to inspection, with leave of the court, judge, or justices, before whom the prosecution shall be.

And after condemnation, the said goods shall be publicly sold by the candle for exportation; half of the produce by

such sale to be to the king, and half to the officer who shall seize and secure the same; and the same goods shall not be delivered out of the warehouse, till security shall be given for exportation, and that the same shall not be landed again in any part of his majesty's dominions.

By 5 Geo. III. c. 48, if any foreign manufactured silk-stockings, silk-mitts, or silk-gloves, shall be imported into this kingdom, or any part of the British dominions, the same shall be forfeited, and liable to be searched for and seized as other uncustomed goods; and every person who shall import the same, or be assisting therein, and the vendors and retailers in whose custody they shall be found, or who shall sell or expose the same to sale, or conceal with intent to prevent the forfeiture, shall, over and above the forfeiture of the goods, forfeit 200*l.*, with costs; half to the king, and half to the officer who shall inform and prosecute.

And when the goods seized (being out of the limits of the bills of mortality) shall not exceed the value of 20*l.*, two justices may proceed to the condemnation thereof. And the proceedings, in all other respects, shall be in like manner as in the case of ribbands and laces above mentioned.

SILK, in *Chemistry*, deserves notice on account of a peculiar salt, or crystalline substance, obtained from it by the nitric acid. In its natural state, or before it is bleached, it contains a yellow resinous matter, from which it derives its fine golden colour. When raw silk is infused in water, a portion of gummy matter is dissolved, and a light amber-coloured liquor is produced. Pure alcohol extracts a much deeper yellow colour, and makes a tincture, that loses none of its colour by long exposure to the sun, which bleaches the silk itself. Nitrous acid acts powerfully on silk, in proportion to its concentration. If two drachms of this acid are mixed with a pint of alcohol, and silk, either raw or bleached, be immersed in it, and kept in digestion, in a moderate warmth, for twenty-four hours, the silk becomes of a dull yellowish-brown, which, after rinsing and washing with soap, and drying, turns to a fine golden yellow, which is very permanent. But when concentrated nitric acid is distilled off silk, and the remaining liquor duly evaporated, much oxalic acid is obtained; and the residue, if evaporated still further, yields, together with a little remaining oxalic acid, a quantity of yellow granular crystals, very bitter, not acid, and staining the saliva and hands of a very deep yellow, not easily removed. If the liquor is previously saturated with potash, and evaporated, another yellow silky salt evaporates, which detonates on coals like common nitre, and appears to be a triple combination of the former bitter substance with nitrate of potash. The first mentioned granular crystals, examined with a magnifier, appear to be composed of truncated octohedrons.

The above curious substance was discovered by Welter, and called by him the "bitter principle." He supposes it to be generally produced by the action of nitric acid on animal matters; and it is perhaps the same substance which causes the bitterness of bile. Aikin.

The spirit of raw silk, rectified with some essential oil, is the medicine commonly known by the name of *Gutta Anglicana*, or English drops.

SILK, *Spider*. Within about a century the secret has been found in France, of procuring and preparing silk from the webs of spiders; and the using it in several manufactures has been attempted. This discovery is owing to M. Bon, in 1710, who published a dissertation on the subject, whence what follows is extracted.

Spiders are usually distinguished, either with regard to their colour, as into black, brown, yellow, white, &c. or with regard to the number, or arrangement, of their eyes; some having six, others eight, others ten. But with regard to the silk-spiders, M. Bon reduces them all to two kinds; those with long legs, and those with short: which last are those which furnish the finest raw silk. The silk-spider makes a silk every whit as beautiful, glossy, and strong, as the silk-worm: it spins it from the anus; around which are five papillæ, or small nipples; and behind these, two others, all muscular, and furnished with sphincters. These nipples serve as so many wire-drawing irons, to form and mould a viscous liquor, which, when dried in the air, after being drawn through them, makes the silk. Each of these nipples, M. Reaumur observes, consists of a number of less and insensible ones; which one may be convinced of by pressing a spider's belly between the fingers, to oblige the liquor to flow into the nipples; for by this means, applying the finger against the anus, several distinct threads will be drawn out through the several perforations of each nipple. The threads are too fine to be counted with any certainty; but M. Reaumur reckons each larger nipple may send forth a great many.

Hence we see how the spiders make their threads bigger or smaller: for as, before they begin to spin, they always apply more or fewer of these nipples against the body whence the web is begun; or, as they apply each more or less strongly; so, as more or fewer of the minuter nipples come to take, the thread thus spun will be a compound of more or fewer of the single threads. Indeed, as the threads come from the anus all joined together, they appear to be single; but M. Bon has distinguished one of the single ones to consist of fifteen or twenty distinct threads.

The threads are of two kinds: the first is weak, and only serves for that kind of web with which they catch flies. The second is much stronger, and serves to wrap up their eggs in; which, by this means, are sheltered from the cold, as well as from insects, which might otherwise gnaw and destroy them. These threads they wind very loosely round the eggs, resembling the balls or bags of silk-worms, that have been prepared and loosened for the distaff.

The spider-bags are of a grey colour, when new; but they turn blackish, when long exposed to the air: indeed, one might find other spiders' bags of other colours, and which would afford a better silk; but their scarcity would render the experiment difficult: for which reason, we confine ourselves to the bags of the most common spiders, which are the short-legged kind. These always find out some place, secure from the wind and rain, to make their bags; as hollow trees, the corners of windows, or vaults, or under the eaves of houses.

By collecting a quantity of these bags, a new silk is made, inferior in nothing to the common silk. It takes all kinds of dyes, and may be made into all kinds of stuffs. M. Bon had stockings and gloves made of it, which he presented to the Academy, and others to our Royal Society.

For the manner of preparing the bags to get the silk, it is thus: after having gathered twelve or thirteen ounces of these bags, M. Bon had them well beaten for some time, with the hand, and a stick, to get out all the dust; he then washed them in lukewarm water, till they left the water very clean: after this, he laid them to steep, in a large vessel, with soap, and saltpetre, and gum arabic. The whole was left to boil, over a gentle fire, for three hours. The bags were next washed in warm water, to get out the soap; and after all, laid to dry some days, to fit them

for carding; which was performed by the common silk-carders, but with cards much finer than ordinary. By this means, he had a silk, of a very particular ash-colour, which was easily spun; and the thread spun from it was both stronger and finer than that of common silk; which shews, that all sorts of works may be made of it: nor is there any reason to fear, but it will stand any trials of the loom, after having passed that of the stocking-weavers.

The only difficulty, now, is in procuring a sufficient quantity of spider-bags to make any considerable work of it; which, M. Bon observes, would be no difficulty at all, had we but the art of breeding them, as we do silk-worms; for they multiply much more; every spider laying six or seven hundred eggs, whereas the silk-worms do not lay above one hundred: yet are these last so tender, &c. that one half die without making any bags, or are hindered, by some little accident, from making them; whereas the spiders hatch of themselves, without any care, in the months of August and September, in fifteen or sixteen days after they are laid; the old spiders that lay them dying soon after. The young ones thus bred live ten or twelve months without eating, and continue in their bags without growing, till the hot weather, putting their viscid juices in motion, induces them to come forth, spin, and run about to seek food. Were a method, therefore, found of breeding young spiders in rooms, they would, doubtless, furnish a much greater quantity of bags than silk worms do. For of seven or eight hundred young spiders, which M. Bon kept, hardly one died in a year; whereas of one hundred silk-worms, not forty lived to make their bags. M. Bon, having ordered all the short-legged spider, that could be found in the months of August and September to be brought to him, shut them up in paper coffins, and pots; covering the pots with papers, which he pricked full of pin-holes, as well as the coffins, to give them air. He fed them with flies, and found, some time afterwards, that the greatest part of them had made their bags. The same ingenious person found, that spider's bags, with regard to their weight, afford much more silk than those of the silk-worms: as a proof of which, he observes, that thirteen ounces yield near four ounces of clear silk, two ounces of which will make a pair of stockings; whereas stockings of common silk weigh seven or eight ounces.

Nor is there any venom in the silk, or even in the spider, as many have imagined. M. Bon has been bit by them several times, without any manner of harm; and as for the silk, it is used with very good success to stop bleeding, and cure wounds, the natural gluten of it acting as a kind of balsam. It likewise yields, by distillation, several specific medicines, particularly great quantities of spirit, and volatile salt, which being prepared after the same manner as that drawn from the bags of silk-worms, in making the gutta Anglicana, or English drops, at one time so famous

all over Europe, may serve to make other drops of greater efficacy, which M. Bon calls drops of Montpellier, and advises to be used in all sleepy diseases.

M. Reaumur, being appointed by the Royal Academy to make a farther inquiry into this new silk work, has raised several objections and difficulties against it; which are found in the Memoirs of the Academy for the year 1710. The sum of what he has urged amounts to this. The natural fierceness of the spiders renders them unfit to be bred and be kept together: four or five thousand being distributed into cells, fifty in some, one or two hundred in others, the big ones soon killed and eat the less, so that, in a short time, there were scarcely left one or two in each cell; and to this inclination of mutually eating one another, M. Reaumur ascribes the scarcity of spiders, considering the vast number of eggs they lay.

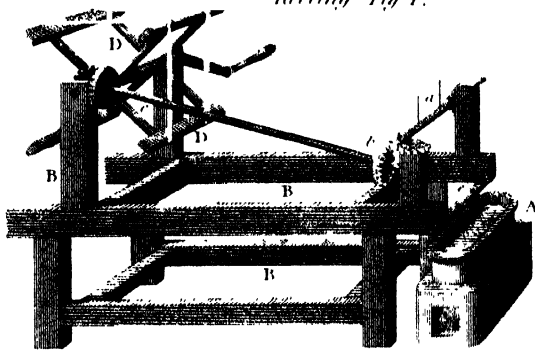
But this is not all: he even affirms, that the spider's bag is inferior to that of the silk-worm, both in lustre and strength; and that it produces less matter to be manufactured. The thread of the spider's web, he says, only bears a weight of two grains without breaking; and that of the bag bears thirty-six. The latter, therefore, in all probability, is eighteen times thicker than the former; yet it is weaker than that of the silk-worm, which bears a weight of two drachms and a half: so that five threads of the spider's bag must be put together, to equal one thread of the silk-worm's bag.

Now it is impossible these should be applied to justly over one another, as not to leave little vacant spaces between them, whence the light will not be reflected; and of consequence, a thread, thus compounded, must fall short of the lustre of a solid thread. Add to this, that the spider's thread cannot be wound off, as that of the silk-worm may, but must of necessity be carded; by which means, being torn in pieces, its evenness, which contributes much to its lustre, is destroyed. In effect, this want of lustre was taken notice of by M. de la Hire, when the stockings were presented to the Academy.

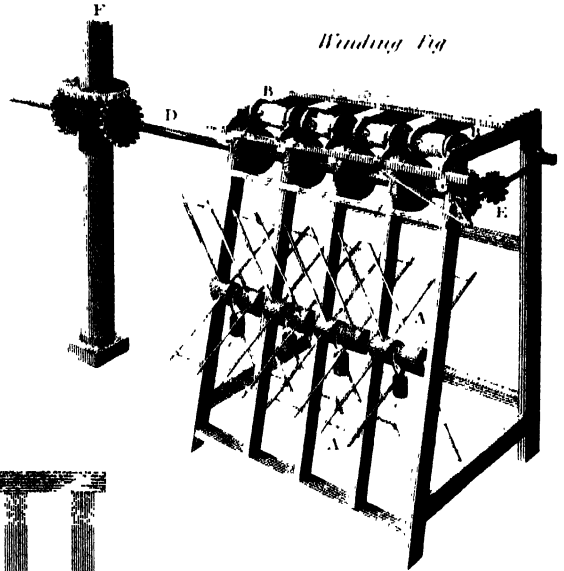
Again: spiders furnish much less silk than the worms: the largest bags of these latter weigh four grains; the smaller, three grains; so that 2304 worms produce a pound of silk. The spider-bags do not weigh above one grain; yet when cleared of their durt and filth, they lose two-thirds of their weight. The work of twelve spiders, therefore, only equals that of one silk-worm; and a pound of silk will require at least 27,648 spiders. But as the bags are wholly the work of the females, who spin them to deposit their eggs in, there must be kept 55,296 spiders to yield a pound of silk. Yet will this only hold of the best spiders; those large ones ordinarily seen in gardens, &c. scarcely yielding a twelfth part of the silk of the others: 280 of these, he shews, would not yield more than one silk-worm; 663,552 of them would scarcely yield a pound.

SILK MANUFACTURE

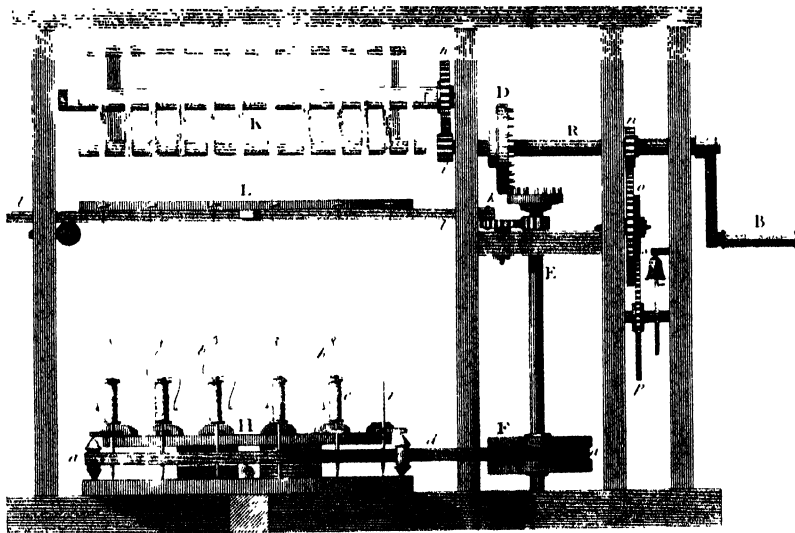
Reeling Fig 1.



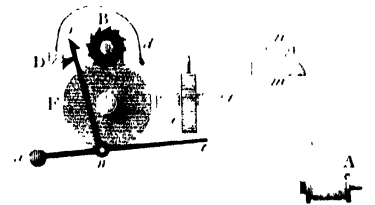
Winding Fig



Throwing Fig 3



Doubling Fig 4



Warping Fig 6

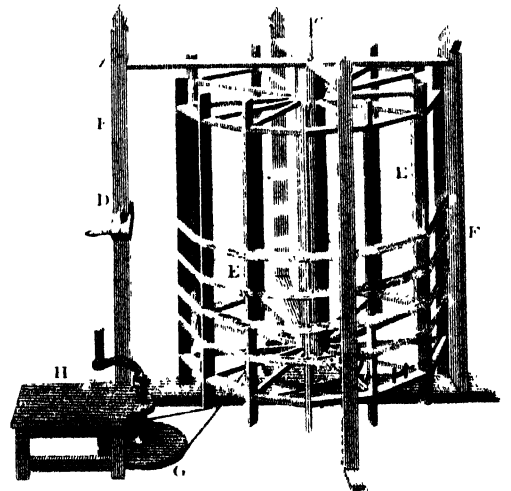
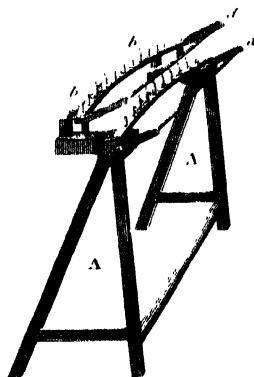
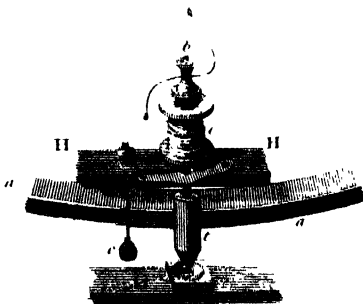
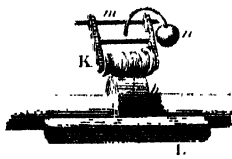


Fig 5



Silver

SILVER, in the *Arts, Manufactures and Commerce*, and in *Domestic Economy*, is a white malleable metal, susceptible of a fine polish. In *Chemistry*, it is a simple inflammable body.

It is sometimes found in the native state, but more frequently combined with antimony, arsenic, or sulphur; forming the varieties of silver-ores; with which we shall begin, and then proceed to the assay and analysis, physical properties, and chemical properties of silver.

Silver-ores contain that metal either native, or alloyed with other metals, or mineralized by sulphur, and sometimes with the muriatic acid, the sulphuric acid, and in one rare instance with the carbonic acid.

Silver-ores principally occur in the rocks which have been denominated primary and transition rocks, and rarely in secondary rocks; but many rich argentiferous lead-ores occur in alpine lime-stone and secondary strata. The ores of silver are accompanied by calcareous spar and sulphate of barytes, and sometimes with quartz, horn-stone, jasper, and fluor spar. It has been remarked, that the warmer regions of the globe afford the greatest quantity of gold, but the richest repositories of silver are situated either in high latitudes or in elevated regions. The most celebrated silver-mines of Europe are in Sweden and Norway, at no great distance from the polar regions; and those which are in warmer latitudes, are almost all situated near the summits of alpine mountains commonly covered with snow, as at Allemont in France, and the mines of Mexico and Peru, in the centre of the Cordilleras. Silver never occurs, like gold, in alluvial soil, or the sands of rivers. After the mineralogical description of the ores, we shall give a short account of the principal repositories of silver at present known.

Native silver, Argent natif of Haüy, possesses the characters of silver extracted from other silver-ores, but is generally less malleable. The colour is pure white, but the surface is commonly tarnished, and is of a yellowish-brown or greyish-black. Native silver occurs crystallized in cubes and octohedrons; the crystals are small, and are often aggregated, forming beautiful ramifications; the branches sometimes cross each other in a rectangular direction, and are reticulated. It is sometimes in leaves and sometimes capillary, and when the filaments are much entangled, it becomes nearly compact. Native silver is also found in shapeless masses of considerable size. In the year 1750, there was found in the famous mine of Hemmels Furst, near Freyberg, in Saxony, a mass of native silver, which weighed one hundred weight and a quarter; in 1771 an

equally large mass was found. It is also mentioned by Albini, in his "*Meissnische Berg Arconicke*," p. 30, "that at Schneeberg, in 1478, a rich silver vein was discovered, and so large a block of native silver cut out, that duke Albert of Saxony descended into the mine, and used this large block as a table to dine upon. It was smelted into four hundred centners of silver: a centner is 110 lbs." (Jameson's Mineralogy.) Native silver is fusible into a globule, which is not altered by a continuance of the heat: it is scarcely ever pure: the metals with which it is alloyed are commonly gold, copper or arsenic, and iron. Native silver alloyed with gold is rare; its colour is intermediate between silver-white and brass-yellow; it often contains a considerable proportion of gold. The stones which form the matrix of native silver in the mine are very numerous; it sometimes appears to be infiltrated into the fissures, sometimes to vegetate on the surface, and in other instances to be intimately combined with the substance of the stone. It is found in almost all the silver-mines that are worked in Europe or America; but the masses discovered in America are not so large as some which have been found in Europe. The *pacos*, a most abundant ore in Peru and Mexico, consists of minute particles of native silver, intermixed with brown oxyd of iron; but the particles are too small to be seen without a lens, and bear but a very small proportion to the mass. Silver rarely occurs in detached grains, like gold or platinum.

Antimonial silver-ore is composed of silver combined with antimony, without any other substance. Its colour is tin-white; it has a shining metallic lustre, which is often tarnished superficially reddish or yellowish. It is distinguished from native silver by its brittleness, being scarcely malleable: the structure is lamellar. It is commonly found crystallized in four-sided and six-sided prisms, having the sides deeply striated: its specific gravity is from 9.4 to 9.8. It melts easily before the blowpipe, giving a white smoke from the oxyd of antimony, and leaving a globule of silver. Its constituent parts are from .76 to .84 silver, and from 16 to 24 of antimony. Antimonial silver is rare, particularly the regular crystallizations of it. It occurs in veins with calcareous spar and sulphate of barytes, and is accompanied by galena and native silver. The foliated structure of antimonial silver distinguishes it from white cobalt-ore, which has a granular structure; it differs also from arsenical pyrites, both by its structure and softness; the latter is extremely hard. Antimonial silver yields to the knife.

Arsenical silver-ore is harder than the former species; its

structure is less perfectly lamellar, the fracture more even, and the lustre weaker. It occurs in small, globular, and kidney-shaped masses; before the blowpipe it yields the smell of garlic, peculiar to arsenic; a globule of silver more or less pure remains. The constituent parts of this ore are given by Klaproth as under;

Silver	-	16
Arsenic	-	35
Iron	-	44
Antimony	-	4

Arsenical silver-ore usually occurs with native arsenic; dark red silver-ore, brittle silver-glance, lead-glance, and brown blende, in calcareous spar. It is a scarce mineral.

Corneous silver-ore, or *Horn-ore*; *Argent muriaté*, Fr. This mineral is distinguished by its translucency; it has a waxy or glistening lustre, is soft and tenacious, and yields to the nail. From these characters it is supposed to bear some resemblance to horn, whence its name. The most common colours of this mineral are pearl-grey, passing into greenish or reddish-blue or brown; it acquires a brownish tarnish. Horn-silver occurs crystallized in small cubes, and is sometimes, though rarely, acicular and capillary: it is more commonly in laminae or small masses, or forms a coating on native silver. It is fusible in the flame of a candle. Under the blowpipe, on charcoal, it yields a globule of silver, and gives out a disagreeable odour, from the escape of the muriatic acid. Its specific gravity is from 4.75 to 4.80. Horn silver-ore is accompanied with native silver, black silver-ore, brown oxyd of iron, quartz, and sulphate of barytes. It is supposed by some mineralogists to be the most recent formation of silver-ore. It occurs in veins in the silver-mines of Europe and America, and in Siberia, and is observed generally to occupy the upper part of the vein. According to Klaproth, it consists of 68 parts silver, 21 muriatic acid, a small quantity of sulphuric acid, with a portion of iron and earthy substances; but the latter may be considered as accidental. Horn-silver is rather a scarce mineral.

Vitreous silver-ore; *Silver-glance*, or *sulphuretted silver*; *Glaferz*, Werner; *Argent sulfuré*, Haüy. Its colour is a dark lead-grey; it is malleable, and may be cut with a knife; the surface, when cut, is shining, and has a metallic lustre; in its natural state it has often an iridescent tarnish. It occurs in a variety of forms, in branches, fibres, small irregular masses, and laminae, and is also frequently crystallized: the crystals are commonly the cube or octahedron, and the dodecahedron, with rhomboidal faces: the fracture is flatly conchoidal. The specific gravity of this ore is from 7.0 to 7.2: its constituent parts are from 73 to 85 silver, and from 15 to 25 of sulphur. When raised to a red heat, the sulphur is gradually sublimed, and the silver appears in filaments, dendritical or reticulated. Many mineralogists suppose that capillary native silver owes its formation very frequently to a similar kind of decomposition of vitreous silver-ore. This mineral occurs in veins, and is always accompanied with other ores of silver, and with galena, iron pyrites, brown blende, sulphate of barytes, calcareous spar, and quartz. It is found in almost all silver-mines in various parts of the globe.

Brittle vitreous silver-ore; *Shrod glaferz*, Werner; *Argent noir*, Haüy; differs from the former by its brittleness, splendour, and colour. The colour is intermediate between iron-black and dark lead-grey; it is brightly splendid externally; internally it alternates from shining to glistening; the lustre is metallic. It occurs massive and disseminated, and in thin small plates, and frequently crystallized in six-sided prisms, variously terminated, and in rectangular four-

sided tables: the latter crystals frequently intersect each other, forming the cellular structure. The tabular crystals are generally minute. The fracture of the massive vitreous ore is uneven; that of the crystals imperfectly conchoidal. This ore is soft, brittle, and fusible by the blowpipe; the sulphur, arsenic, and antimony, are partly volatilized, and a globule of imperfectly malleable silver, accompanied with a brown scoria, remains. According to Klaproth, the brittle vitreous silver-ore, from a mine near Freyberg, contained

Silver	-	66.50
Sulphur	-	12
Antimony	-	10
Iron	-	5
Copper and arsenic	-	0.50
Earthy matter	-	

Black sulphuretted silver-ore; *Silber schwarz*, Werner; differs from vitreous silver-ore by its want of lustre: it occurs massive, corroded, and in powder: the fracture of the former is uneven; the streak shining and metallic. It yields to the knife, and is fusible into a slag, containing globules of silver.

Red silver-ore, or *Ruby silver*; *Roth gilitgerz*, Werner; *Argent rouge*, and *Argent antimonie sulfuré*, Fr. The colours of this mineral are various shades of red, passing from a bright-red to dark-red, and reddish-grey or black. When scraped, the powder is of a crimson colour. The crystallized varieties are translucent, or semi-transparent, and the transmitted light is a carmine, light blood, or cochineal-red. It occurs massive, disseminated, and in thin plates, and crystallized in hexahedral prisms, variously terminated, and in dodecahedrons, with triangular faces, nearly similar to the crystallization of calcareous spar, called dog-tooth spar. The primitive form of the crystal, according to Haüy, is an obtuse rhomboid, whose plane angles are $104^{\circ} 28'$ and $73^{\circ} 22'$, and the inclination of the faces $109^{\circ} 28'$ and $70^{\circ} 32'$. The fracture is usually uneven, and imperfectly conchoidal; its lustre externally is shining and metallic, internally glimmering, sometimes metallic. It is brittle, soft, yielding easily to the knife. Before the blowpipe it gives out a copious smoke, with an arsenical smell, and leaves a globule of silver. Its specific gravity is about 5.6. There are several minerals which have a red colour, and may at first sight be confounded with red silver, as the sulphuret of arsenic, or realgar; but this mineral becomes yellow when powdered. Cinnabar has a greater resemblance, but the specific gravity is 7, and it is entirely volatilized by the blowpipe. Red oxyd of copper has a specific gravity of 3.9, and is usually accompanied with native copper, malachite, and brown iron ochre; it also effervesces with nitric acid, and communicates to a solution of ammonia a blue colour. By these characters it may be known from red silver-ore. Werner has divided red silver-ore into two sub-species, the light and the dark. Klaproth analysed this mineral, and found it to contain only silver, sulphur, antimony, and oxygen. Proust has shewn that there are two kinds of red silver-ore, the one containing arsenic, and the other antimony. The constituent parts, as given by Klaproth and Vauquelin, are

	Klaproth.	Vauquelin.
Silver	60	54.27
Antimony	20.3	16.13
Sulphur	11.7	17.75
Oxygen	-	11.85
Sulphuric acid	8	

According to the analysis of Proust, a variety of this ore contained nearly .75 parts of metallic silver, and .25 of metallic arsenic. Red silver-ore occurs in veins, but is always intermixed with other minerals, particularly with compact galena, cobalt, sulphuret of arsenic, native arsenic, grey copper-ore, and sparry iron-ore; and has a matrix of calcareous spar, sulphate of barytes, fluor spar, or quartz. It is a common ore in silver-mines, both in Europe and America: the dark-red ore is considerably more productive than the light-red.

Silver amalgam consists of pure silver combined with mercury. It has been found in the silver-mine of Salberg, in the province of Dalecarlia, in Sweden, in the mines of Deux-Ponts, in the Palatinate, and in some other places, either in thin plates or grains, or crystallized into octohedrons and dodecahedrons. It is sometimes semi-fluid. Its colour is silvery-white or grey, the fracture conchoidal, and the lustre metallic. It is soft, breaks when cut, and whitens the surface of gold or of copper; when rubbed upon them warm before the blowpipe the mercury evaporates, and leaves the silver pure. The constituent parts, given by Klaproth, are

Silver	-	-	-	-	36
Mercury	-	-	-	-	64

White silver ore has a near resemblance to compact galena. The colour is a light lead-grey, passing to steel-grey: it occurs massive and disseminated, and is generally intermixed with cubic galena. The fracture is most commonly even, but sometimes fine-grained and uneven, and also fibrous; the internal lustre is glistening and metallic; the streak shining. It is soft and brittle. The specific gravity is 5.3. Some mineralogists think this ore should be classed with the argentiferous ores of lead. According to Klaproth, different specimens from Hemmels Furst, near Freyberg, contain, of the

	Dark-white silver-ore.	Light-white silver-ore
Lead	- 41	48
Silver	- 9.25	20.40
Antimony	- 21.50	7.88
Iron	- 1.75	2.25
Sulphur	- 22.0	12.25
Alumine	- 1.0	7
Silex	- 0.75	0.25

Carbonate of Silver.—This ore has hitherto been only discovered in the silver-mine of Winceslaus, in Swabia: it occurs sometimes in masses, and sometimes disseminated through other minerals. Its colour is a greyish-black; its fracture uneven, with a glistening metallic lustre; it is brittle and heavy, and effervesces with acids; it melts easily under the blowpipe. According to Mr. Selb, who first described this mineral, it contains

Silver	-	-	-	72.5
Carbonate of antimony	-	-	-	17.5
Carbonic acid	-	-	-	12

It contains also a slight trace of copper.

Besides the above ores of silver, there are ores of other metals which contain a portion of silver, and have been classed by some mineralogists with silver-ores. An argentiferous variety of grey copper-ore, of an iron-black or steel-grey colour, has received the name of black silver-ore. It occurs massive, disseminated and crystallized in tetrahedrons; the fracture is small conchoidal, with a shining metallic lustre; it is sectile and brittle. An ore which is a combination of lead, bismuth, and silver, has received the name

of bismuthic silver. Its colour is a light lead-grey: it occurs disseminated, but rarely ever in masses; the fracture is fine-grained, uneven, with a glistening metallic lustre; it is soft and rather brittle; before the blowpipe metallic globules appear on the addition of borax, which unite; the button is brittle, and of a tin-white colour: the flux acquires an amber colour. According to Klaproth this ore contains

Lead	-	-	33
Bismuth	-	-	27
Silver	-	-	15
Iron	-	-	4.3
Sulphur	-	-	16.3
Copper	-	-	0.9

Argentiferous lead-ores are common in Great Britain and in various parts of Europe. Many of these ores are not sufficiently rich to repay the expense of extracting the silver. It is procured in considerable quantities in North Wales, the north-west parts of Yorkshire, and in the counties of Durham and Northumberland. Indeed, many lead-ores in these counties contain a much larger portion of silver than the average proportion of that metal in the ores of Mexico and Peru; but mineralogists do not class them with silver-ores.

Silver Mines in Great Britain.—Silver-ores, properly so called, are of rare occurrence in our island. A few years since, a vein of silver was worked with great profit in the parish of Alva, in the county of Stirling, in Scotland. The ores were native silver, and vitreous silver-ore. From forty to fifty thousand pounds sterling value was extracted before the ore was exhausted, after which the search to recover the vein proved fruitless, and since that time no silver-mines have been worked in that country. The silver-ores at Alva were accompanied with copper, lead, and cobalt-ores, with a matrix of calcareous spar, and sulphate of barytes. It is supposed by Dr. Millar that the veins traverse rocks of argillaceous porphyry.

Cornwall and Devonshire yield the richest argentiferous lead-ores of any part of Great Britain; but the quantity of these ores is small. In the former county a small quantity of native silver, with other silver-ores, have been occasionally found. We have been favoured with the following account of the present state of the silver-mines in these counties from Mr. Mawe, author of Travels in Brazil, who visited them in the summer of 1815.

From the lead-mines of Ben-Allten, in Devonshire, a large quantity of silver has been extracted. The vein is situated in *killas*, (see SLATE,) and is filled chiefly with fluor spar and galena. It has been worked to the depth of 110 fathoms: the silver extracted from the north and south vein averages about 70 ounces to the ton of lead. Another vein, running in a more easterly and westerly direction, situated in the same *killas*, produces 170 ounces of silver in the ton of lead. The vein is worked under the river Tamar. These mines are of considerable importance; during the last six weeks, the silver extracted from the lead procured here exceeded six thousand ounces. The works are extensive, and said to be well conducted.

About four miles to the south-east of Callington is a silver-mine of another description: the vein is situated in a similar rock of *killas* or chlorite slate. The vein was first worked for copper, but native silver and lead-ore were discovered in it. The mine is called Huel Jewel: the thickness of the vein rarely exceeds three or four inches. In many of the cavities were found a considerable quantity of capillary native silver, with galena, red silver-ore, and sulphuret of

silver. The ores were exceedingly rich, and promised at one time an ample recompence to the adventurers.

The Hurland copper-mine, near Redruth, has produced a considerable quantity of native silver in a small vein, branching from the principal vein. Some of the fibres of silver were more than four inches long.

There is a lead-mine near Truro worked at this time, and a considerable quantity of silver is extracted from the lead, as it yields 100 ounces *per* ton.

Near Peranzabula, on the north coast of Cornwall, there was a mine formerly worked close to the sea, which produced lead-ores in various states, and a portion of horn-silver, fine specimens of which are in various cabinets. Mr. Mawe found some specimens of this rare mineral among the refuse of the mine.

At Comb-Martin, in North Devon, are some lead-mines, which were formerly celebrated for the silver, but at present they are not productive.

Argentiferous lead-ores are the common lead-ores of the northern counties and of Wales; they vary in the quantity of silver they contain, from a few ounces to 40, 60, or 80 ounces of silver *per* ton. Some few rare instances have occurred in the north-west part of Yorkshire, of their exceeding the latter amount. On the average, the argentiferous lead that is calcined to extract the silver does not contain 20 ounces *per* ton: by some it has been stated at 17 ounces.

According to Lehman, there are no known lead-ores in the world but what contain silver, except that of Villoch, in Carinthia. (Lehman sur les Mines.) But according to Dr. Watfon, the quantity of silver necessary to defray the expence of extracting, and the loss of lead, was nine ounces *per* ton, when lead was at the price of 15*l.* *per* ton. The price of lead is now 26*l.* *per* ton, and though silver be also advanced, yet the difference in the relative prices of each, taking the above as a standard, is such, that to repay the expence of extraction, the lead should contain about fifteen ounces of silver in every ton.

It is not to be expected that the proprietor of any lead-mines rich in silver should be forward in declaring to the world the quantity of silver they contain. The proprietor of the lead-mine containing silver may indeed work the same without any apprehension of its being taken from him under the pretence of its being a royal mine; yet the crown, and persons claiming under it, have the right of pre-emption of all the ore which may be raised. There was an act of parliament passed in the sixth year of William and Mary, entitled, An act to prevent disputes and controversies concerning royal mines. This act declared, that every proprietor of a mine of copper, tin, iron, or lead, should continue in possession of the same, notwithstanding its being claimed as a royal mine, from its containing silver or gold; but it is further enacted, that the crown, or persons claiming under it, should have the privilege of purchasing all the ore which should be raised out of such mine, at the following prices, when made clean and merchantable: for copper-ore, at the rate of 16*l.* *per* ton; for tin-ore, except that of Devonshire and Cornwall, 40*s.*; for iron-ore, 40*s.*; and for lead-ore, 9*l.* The standard price then fixed, particularly for lead, was much higher than the ordinary price of the ore in which there was no silver. Owing to the existence of this act, it is probable that we are not acquainted with the quantity of silver at present extracted annually. We are informed, that the value of silver produced by the lead-mines of colonel Beaumont, in Northumberland and Durham, is not less than 4000*l.* sterling *per annum*; and other large proprietors also extract a considerable quantity of silver from the lead-ores in

the northern counties. At present we believe that there is no silver extracted from the Derbyshire lead-ores.

It appears from Hollingshed's Chronicle, that silver was formerly extracted from lead in various parts of the island. In the reign of Edward I. 1600 pounds weight of silver was obtained in the course of three years, from a mine in Devonshire, which had been discovered towards the beginning of his reign: this mine is called a silver-mine by the old writers, but it appears to have been a mine of lead that contained silver. The lead-mines in Cardiganshire have at different periods afforded great quantities of silver: sir Hugh Middleton is said to have cleared from them two thousand pounds *per* month, and to have been enabled thereby to undertake the great work of bringing the New River from Ware to London. The same mines yielded, in the time of Charles I. eighty ounces of silver in every ton of lead, and part of the king's army was paid with this silver, which was minted at Shrewsbury. Sir J. Pettie's Essay on Metal Works.

A mint for the coinage of Welsh silver had been previously established at Aberystwith; the indenture was granted to Thomas Bushel, for the coinage of half-crowns, shillings, sixpences, twopences, and pennies, and the monies were to be stamped with the oltrich feathers on both sides. In 1604 nearly 3000 ounces of this Welsh bullion were minted at one time at the Tower. Webster, in his History of Metals, published in 1671, makes mention, from his own knowledge, of two places in Craven, in the West Riding of Yorkshire, where formerly good argentiferous lead-ore had been procured. One of the places was Bronghite Moor, in the parish of Slaidburn; the ore held about the value of 67 pounds of silver in a ton: the other was at Skelkhorfield, in the parish of Gisburn; it had formerly belonged to a person of the name of Pudsey, who is supposed to have coined it, as there were many shillings in that country which the common people called Pudsey shillings. There are several smelting-houses at Holywell, in Flintshire, where silver is extracted from lead. According to Mr. Pennant, at one of the largest of these houses in the year 1754, more than 12,000 ounces of silver were produced, but in the subsequent years the quantity of silver appears to have considerably diminished. The silver extracted from lead is sold principally to the manufacturers at Sheffield and Birmingham.

The silver is extracted from the lead by the oxydation of the latter metal in a reverberatory furnace of a particular construction, for the admission of air on the surface of the lead in a state of fusion.

A shallow vessel or cupel is filled with prepared fern-ashes rammed down, and a concavity cut out for the reception of the lead, with an opening on one side for the mouth of the bellows, through which the air is forcibly driven during the process. The French smelters cover the surface of the ashes with hay, and arrange symmetrically the pieces of lead upon it. When the fire is lighted, and the lead is in a state of fusion from the reverberation of the flame, the blast from the bellows is made to play forcibly on the surface, and in a short time a crust of yellow oxyd of lead, or litharge, is formed, and driven to the side of the cupel opposite to the mouth of the bellows, where a shallow side or aperture is made for it to pass over; another crust of litharge is formed and driven off, and this is repeated in succession till nearly all the lead has been converted into litharge and driven off. The operation continues about forty hours, when the complete separation of the lead is indicated by a brilliant lustre on the convex surface of the melted mass in the cupel, which is occasioned by the removal of the last crust of litharge that covered the silver. The French introduce water through a tube into the cupel, to cool the silver rapidly and prevent

its spirting out, which it does when the refrigeration is gradual, owing probably to its tendency to crystallize. In England the silver is left to cool in the cupel, and some inconvenience is caused by the spirting, which might be avoided by the former mode.

The silver thus extracted is not sufficiently pure; it is again refined in a reverberatory furnace, being placed in a cupel lined with bone-ashes and exposed to a greater heat: the lead which had escaped oxydation by the first process is converted into litharge, and absorbed by the ashes of the cupel.

The last portions of litharge in the first process are again refined for silver, of which it contains a part that was driven off with it. The litharge is converted into lead again, by heating it with charcoal; part is sometimes sold for a pigment, or converted into red lead. The loss of lead by this process differs considerably, according to the quality of the lead. The litharge commonly obtained from three tons of lead amounts to 58 hundred weight; but when it is again reduced to a metallic state it seldom contains more than 52 hundred weight of lead, the loss on three tons being about eight hundred weight. The Dutch are said to extract the silver from the same quantity of lead, with a loss of only six hundred weight.

Silver-Mines of France.—The mine of Allemont, ten leagues from Grenoble, in the department of Isere, is situated near the summit of a mountain, composed of thin beds of mica-slate and hornblende, curiously contorted and broken. Its elevation is about 3000 yards above the level of the sea. The veins are numerous, and run in all directions: the mineral appears to have filled also numerous fissures in the rock. The ores are native silver, vitreous silver, red silver-ore, and horn-silver. Silver appears also disseminated in a kind of ferruginous clay, and is accompanied with various ores of cobalt, antimony, arsenic, and nickel. The matrix was ferruginous clay and carbonate of lime, mixed with asbestos, epidote, and calcareous spar. The veins were much richer near the surface than at a great depth, and the working of this remarkable mine is at present nearly abandoned. Red silver-ore has also been found in the Vosges, in the department of the Upper Rhine, in a vein of argentiferous copper-ore. Indications of silver have been traced in other districts of France. The lead-ores of some parts of France are also sufficiently rich in silver to repay the expence of extraction.

The *silver-mines of Spain* are the most ancient known in Europe. It appears, as well from the accounts of historians, as from the numerous vestiges of ancient workings, that the operations were carried on to a considerable extent. The most remarkable mine was that at Guadalquivir, in Andalusia, in the Sierra Morena, five leagues to the north of Seville; the ore which it contains is the red or ruby silver, in a matrix of compact galena. Since the discovery of South America no attention has been paid to the mines of Spain, though formerly so productive both of silver and gold.

Germany.—The mining district of Freyberg, in Saxony, contains numerous veins that yield silver. The veins that traverse rocks of gneiss are generally composed of quartz, calcareous spar, and fluor spar; they inclose argentiferous lead, vitreous silver-ores, ruby silver, and grey argentiferous copper-ore. The mine at Annaberg, according to Klapproth, contains muriate of silver (horn-ore) mixed with much clay, which is imbedded in compact lime-stone. The mines of Schneeberg, in Misnia, and of Hartz, in Hanover, contain argentiferous lead, accompanied with proper silver-ores.

Hungary.—The mines of Schemnitz and Kremnitz, in Hungary, have been long celebrated, both for the richness of their productions and the immense extent of the opera-

tions. The rocks in which the mining operations are carried on, are described as being composed of an argillaceous grey-stone, mixed with quartz or schorl, or particles of calcareous spar. To this rock baron Born has given the name of the metalliferous rock, *saxum metalliferum*: it is described by him as containing three principal veins, running from north to south, and parallel with the river Gran, following even the windings of the river. From this circumstance we should infer, that the river itself had originally taken the course of a fracture by another vein. The dip or inclination of all the veins is from west to east, varying from 30 to 70 degrees. In one part of the vein, called the *spitaler vein*, it is joined with an argillaceous white vein, which runs along with it on the *hanging* side, and from the place of junction the vein is found to contain silver. In this white clay are occasionally found nodules of spar and masses of quartz, which yield from four to five ounces of silver in the hundred weight. The second great vein at Schemnitz has nearly the same characters as the first. The third great vein is more irregular in its inclination, and the ores are not so rich in silver, but in some parts it contains a considerable quantity of gold.

Some notion may be formed of the extent of the mining operations at Schemnitz, from the gallery or level called the Emperor Francis' Gallery, by which the whole of the royal mine is drained and cleared of water. This gallery, which forms a very considerable excavation, and is carried through hard rock, was a work of immense labour and difficulty; it is five English miles in length: it was begun in 1748, and finished in 1765.

The mountains round Kremnitz, according to baron Born, are composed of the same metallic rock already described: but according to Patrin, they consist of primitive trap. At this place very extensive operations, which were begun at least a thousand years ago, have been established on a large and rich gold vein, and some of its branches. The rock is a white solid quartz, mixed with fine auriferous red and white silver-ore, and with auriferous pyrites. At the depth of 160 fathoms, the vein continued rich and productive.

Konigsberg is another mining-town of Hungary, some miles to the north-west of Schemnitz. The valley in which this place is situated is bounded on one side by the same kind of metallic rock, and on the other, towards the north, by granite mountains. In the royal mine, at the time it was visited by baron Born, the vein was observed to run between the metallic rock, which formed its *hanging* side, and the granite, which was its *bedding* or lower side. The vein is grey quartz, mixed with auriferous pyrites. The first steam or fire-engine established in the Lower Hungarian mines was erected at Konigsberg, in 1725, by Isaac Porter, an English engineer, who was then in the imperial service.

Bohemia.—The circle of Saatz, in Bohemia, abounds in various metallic ores, among which the ores of silver occasionally predominate. The prevailing rocks are gneiss and argillaceous schistus. The veins at *Catharineberg* traverse gneiss, and generally run in a north and south direction, and parallel to the mountain in which they are situated. But there are also some powerful veins which cross the mountain. One of this nature is described, which seems to be insensibly blended with the mountain rock. The vein-stone is also of the same kind of rock, but occasionally assuming the characters of a variety of granite. It is observed, that the vein, which seldom exceeds a foot in width, diminishes in thickness when the containing rocks become harder; and when the sides are found incrustated with a ferruginous clay, it appears to be richer in ores. Fissures from the sides of the vein are found to improve it: a fine white clay, with

quartz imbedded in it, indicates rich ore; but a coarse clay, destitute of quartz, especially when it increases in quantity, and occupies the whole vein, renders it unproductive, or entirely barren. The ores of the vein now described are rich silver and copper pyrites, with fluor spar, blende, various copper-ores, and sometimes native silver and copper.

Joachimthal, a place in the same circle, has been long celebrated on account of its valuable mines. The prevailing rocks are described as grey micaceous and quartzose clay-slate, which at a great depth became more of an argillaceous nature, soft, foliated, and of a black colour. The mountains around this place have a gentle declivity towards the south, but run in lofty ridges to the east, north, and west, and are intersected by deep vallies. This inequality of surface affords great accommodation to the miners to open numerous galleries, which converge to the south, and to the valley in which stands the town of Joachimthal. All the galleries and works of this district are divided into six different fields, belonging to the same number of companies, and they are drained by two deep drifts or levels; the one of which runs in a direct line 1600 fathoms; but including its several branches, its whole length is 4500 fathoms. The depth under the highest tops of the mountain is 170 fathoms: the second great level, which runs through the space of 5600 fathoms, and in a direct line 1500 fathoms, is 20 fathoms deeper than the first; but the operations in the mines have been carried to a much greater depth; for at the time in which they were visited by Ferber, before 1774, the perpendicular depth under the surface was from 200 to 350 fathoms, and, excepting the mines in the Tyrol, were then considered as the deepest in the world.

The thickness of the veins varies from one inch to two feet; and the vein-stones are a whitish or blueish clay, argillaceous slate, and reddish horn-stone, or petro-silex, which is the matrix of the richest ores. The silver-ores which are found in this mining district are, native silver, which is attached to different vein-stones, and assumes various forms; vitreous silver-ore, which is dug out sometimes in very large masses, and is considered as a very rich ore; one hundred weight being commonly valued at 180 marks of silver: red silver-ore, sometimes beautifully crystallized and transparent, is attached to red horn-stone or calcareous spar; and white silver-ore has sometimes but rarely appeared.

The silver-mines of *Bergstadt*, in the circle of *Tabor*, are in hills of a gentle declivity, and composed of grey or blueish clay-slate, in which appear figures of greenish lithomarge, or semi-indurated pot-stone. These mines were formerly rich in native silver, and other ores of that metal. A vein to the west of this place, which traversed a hard rock, contained reddish-coloured felspar, with galena, blende, and a little silver; but from the part where a vein containing white arsenical pyrites came into the hanging side, the vein produced native silver, vitreous, red, and white silver-ore. Another vein in the same place, which is from two inches to one foot in width, is observed to be richest where it is thinnest. It is chiefly enriched by an undulating black clay fissure, which appears sometimes in the hanging side, and then it produces red and white silver-ore. When crossed by veins running from east to west, it appears to be cut off and barren, till beyond the place of junction it again becomes productive in its former course.

Sweden.—The silver-mines of *Salberg*, in *Westmania*, are about 28 English miles from *Upsal*. The ore is an argenteriferous galena, yielding from one marc to a marc and a half of silver *per* quintal; it is in compact lime-stone, and has been worked to the depth of 150 fathoms. The average profits

amount to about 4000*l.* and one-eighth is paid to the king. *Porter's Travels*.

Norway.—The silver-mines of *Konigsberg*, in *Norway*, are situated in mountains of moderate height, composed of nearly vertical beds of mica-slate with garnets, and of grey quartz mixed with fine black mica, and a little lime-stone and red horn-stone. Other beds are composed of a ferruginous rock, which, in the upper part of the mine, is 33 feet thick, but in the lower not more than 6 feet thick.

The veins are from half an inch to two feet or more in thickness, and cut the strata transversely. The matrix of the ore is granular lime-stone, sometimes intermixed with fluor spar. Enormous masses of native silver have sometimes been found in this mine; one is mentioned as weighing 220*lbs.* The common ores are native silver and vitreous silver. The veins are most productive in the ferruginous rock. The annual produce is about 5000*lbs.* weight of silver.

Asia.—The silver-mines of *Zmeot* are situated in that part of the *Altai* chain of mountains which lies between the *Oby* and *Irtisch*, from 50° to 52° north latitude. The annual produce has been stated at 60,000 marks of silver, which is alloyed with about 3 *per cent.* of gold. The mines of *Nertschink* in *Daouria*, near the river *Amur*, yield argenteriferous galena, producing about 30,000 marks of silver, and containing 1½ *per cent.* of gold. The Russian merchants who trade to China bring back ingots of silver, from several ounces to a pound weight, in exchange for their commodities; hence it may be inferred, says *Patrin*, that there are silver-mines on the frontiers of China. *Patrin, Hist. des Mines.*

America.—The most productive silver-mines in the world are those of *South America* and *New Spain*. Those of *Peru*, for many years after its conquest by the Spaniards, yielded the greatest quantity of silver; but at present the mines of *Mexico* are the richest. The mines of *America* furnish both silver and gold; and in making an estimate of their richness, we must take an account of each of these metals. The following table, given by *M. Humboldt*, will shew the distribution of these mineral treasures in the different parts of the new world; the kilogramme being 2 *lbs.* 3 *oz.* 5 *dr.* *avoirdupois*, or rather more than 2 *lbs.* 8 *oz.* *troy*.

	Gold.	Silver.
Viceroyalty of Peru	782	140,478
Viceroyalty of New Spain	1,609	537,512
Capitania of Chili	2,807	6,827
Viceroyalty of Buenos Ayres	506	110,764
Viceroyalty of Grenada	4,714	
Viceroyalty of Brasil	6,873	
Kilogrammes	17,291	995,581

The above was the annual produce of the different districts, at the beginning of the 19th century; from which it appears, that the total weight of the precious metals from all the mines in *America*, reduced to English pounds *troy*, is 45,580 *lbs.* of gold, and the enormous quantity of 145,000 *lbs.* of silver; equal in weight to one-third of the tin produced by the mines in *Europe*. *Dr. Adam Smith*, in his "Wealth of Nations," values the gold and silver annually exported into *Cadiz* and *Lisbon* at only six millions sterling, including not only the registered gold and silver, but that which may be supposed to be smuggled. This estimate is only two-fifths of the real annual amount.

The mountain of *Potosi* has furnished, since its discovery in 1545, a mass of silver equal in value to 234,093,840*l.*

sterling. The mountain is 18 miles in circumference: it is composed of slate, but has a conical covering of porphyry, which gives it the form of a sugar-loaf, or basaltic hill; it rises 697 toises, or 480 yards, above the surrounding plain. The richness of the veins has diminished, as they have been worked to greater depths. At the surface of the earth, the veins of Rica, Centeno, and Mendieta, which traverse primitive slate, were filled with native silver, and silver-ores throughout their whole extent. These metallic masses rose in ridges or crests above the surface, the sides of the vein having been destroyed either by water or by some other cause. In 1545, minerals containing from 80 to 90 marcs of silver *per* quintal were common. In the year 1574, according to Acosta, the average richness of the ore was eight or nine marcs *per* quintal. In 1607, the mean wealth of the ores was not more than an ounce and a half to the quintal. The ores are now extremely poor, and it is on account of their abundance alone that the works are still in a flourishing state: for from 1574 to the year 1789, the mean quantity of silver in the ores has diminished in the proportion of 170 to 1; while the absolute quantity of silver extracted from the mines of Potosi has only diminished in the proportion of 4 to 1.

About six miles from Pasco is the mountain Jauvichora: it is distinguished by the name of the Silver mountain. It is about half a mile in diameter, and only about 30 yards in depth: it is composed of brown iron-stone, which is interspersed with pure silver. This stone does not yield more than nine marcs of silver in 500 lbs.; but there is a friable white clay met with in the middle of this mass of ore, which yields from 200 to 1000 marcs of silver in every 50 cwt. The mountain is penetrated in all directions, without any attention to security; so that it is expected it may fall in, in the course of a few years. According to Helms, this mountain yields annually 200,000 marcs of silver.

The veins of silver at Potosi are in slate, which Humboldt considers as primitive: this slate is covered with a clay porphyry, containing garnets. The mines of Gualgayoc, in Peru, are in the Alpine lime-stone. The veins which furnish nearly all the silver exported from Vera Cruz are in slate, porphyry, grauwaacke, and Alpine lime-stone: the principal of these veins are those of Guanaxto, Zacatecas, and Catoree. The vein of Guanaxto yields more than one-fourth of the silver of Mexico, and a sixth part of the total produce of America. This vein is, in some parts, from 147 to 150 feet in width, including the branches, and has been wrought from Santa Isabella and San Bruno to Buena-Vista, a length of 42,000 feet. The most celebrated mines in Mexico are elevated from 6000 to 9000 feet above the level of the sea. In the Andes, the mines of Potosi, Ocuero, Pas, Pasco, and Gualgayoc, are in regions higher than the loftiest summits of the Pyrenées. A mass of rich silver-ore has been discovered near the small town of Micuicampa, at the absolute height of 13,450 feet. The great elevation of the Mexican mines is peculiarly advantageous to the working of them, as the climate is temperate, and favourable to vegetation and cultivation.

The part of the Mexican mountains which at present contains the greatest quantity of silver, lies between the twenty-first and twenty-fourth degrees of latitude; and it is not a little remarkable, that the metallic wealth of Peru should be placed at an almost equal latitude, on the other side of the equator. In the vast extent which separates the mines of La Pas and Potosi from those of Mexico, there are no others which throw into circulation a great mass of the precious metals, but those of Pasco and Chota. The

isthmus of Panama and the mountains of Guatemala contain, for a length of 600 leagues, vast tracts of ground, in which no vein has hitherto been worked with success.

The province of Quito, and the eastern part of the kingdom of New Granada, from the eighth degree of south latitude to the seventh degree of north, are equally poor in metallic wealth. It would not, however, says Humboldt, be correct to infer that these countries, which have been convulsed and torn by volcanoes, are destitute of the precious metals. Numerous metallic repositories may be concealed by beds of basalt, and other rocks of supposed volcanic origin. It should, however, be remarked, that some of the rocks, which Humboldt enumerates as very metalliferous, are by other geologists considered of volcanic origin, particularly clink-stone-porphry, and other porphyries containing hornblende, but distinguished by the absence of quartz and common felspar.

The mines of Huantajya are celebrated for the great quantities of native silver they formerly produced. They are situated in an arid desert, and surrounded by rock-salt, near the shores of the Pacific ocean, at no great distance from the small port of Yquique, in the audience of Lima. These mines are a remarkable exception to the great elevation of silver-mines in Spanish America, being placed on a low and gentle declivity. Their produce is native silver, vitreous silver, and horn silver; the annual amount is about 50,000 lbs. troy of silver, or 80,000 marcs.

The silver-mining operations of Chili, according to Humboldt, are in general not productive; but the vein at Uspalata contains *pacos* so rich, that the produce is from 2000 to 3000 marks in every 5000 lbs., or from 40 to 60 marcs *per* quintal. Molina, in his History of Chili, describes the vein at Uspalata, on the Andes, as being nine feet in thickness. It has been traced 90 miles, and is supposed to extend 300 miles. From the main vein there are branches on each side, which extend to the neighbouring mountains: some of these branches are 30 miles in length. This is the largest metallic vein which is at present known in the world.

According to Humboldt, the greatest part of the silver extracted from the bowels of the earth in Peru is furnished by a species of ore called the *pacos*, of an earthy appearance, which M. Klaproth analysed, and was found to consist of almost imperceptible particles of native silver with the brown oxyd of iron. In Mexico, on the contrary, the greatest quantity of silver annually brought into circulation is derived from vitreous silver-ore, grey silver-ore, horn-ore, and black and red silver-ores. Native silver is not extracted in sufficient quantity to form any considerable proportion of the total produce of the mines of New Spain. It is, says this traveller, a very common prejudice in Europe, that great masses of native silver are very common in the mines of Mexico and Peru, and that in general the mines of mineralized silver, destined to amalgamation, or to smelting, contain more ounces, or marcs of silver, to the quintal, than the silver-ores of Saxony or Hungary; but he adds, I was surprised to find that the number of poor mines greatly exceeds those of the mines which, in Europe, would be esteemed rich. It is at first difficult to conceive how the famous mine of Valenciana, in Mexico, can regularly supply 30,000 marcs of silver *per* month, as the vein consists of sulphuretted silver, disseminated in almost imperceptible particles through the matrix. In the formation of these veins, it should appear that the distribution of silver has been very unequal, being sometimes concentrated at one point, and at other times disseminated in the vein through the matrix or *gangue*; for, in the midst of the poorest ores

are found considerable masses of native silver. Although the new continent has not hitherto produced single masses of native silver equal to what have been found in the old, the metal is more abundant in a state of perfect purity in Mexico and Peru than in any other quarter of the globe, not in masses, but in particles disseminated through the enormous quantity of the ore called *pacos*. The result of a general investigation of the richness of different mines is, that the mean richness of the different ores is not more than from three to four ounces of silver in every sixteen hundred pounds of ore. According to this result, the ore contains, on the average, two ounces and two-fifths *per* quintal. It had formerly been asserted, that no ores were worked in Mexico that did not contain one-third part of silver. The silver-ores of Peru are not richer on the average than those of Mexico. The district of Guanaxto has before been mentioned as furnishing more than one-fourth of the silver annually extracted in America, the riches of the mines here being superior to the celebrated repository at Potosi: they are all worked in one extensive vein. Among these mines, that of the count Valenciana is one of the richest: the average produce of silver is four ounces of silver from a quintal of ore.

The whole weight of silver from the vein of Guanaxto, on an annual average from 1786 to the year 1803, has been 556,000 marcs, or 364,911 lbs. troy; and in thirty-eight years the weight of gold and silver, from the same vein, has been 12,700,000 pounds troy. In average years it yields from 500,000 to 600,000 marcs of silver, and from 1500 to 1600 marcs of gold. It has been doubted by some persons whether this be really a vein, or a metallic bed, as in some parts of its course it is parallel between the beds, or strata of the rock. It passes through both slate and porphyry, and is metalliferous in both. Though it has been before stated that the extent of this vein is more than 42,000 feet; yet the enormous mass of silver which it has supplied for the last hundred years, sufficient alone to change the price of commodities in Europe, has been extracted from an extent of less than 2000 feet; for where this vein is not widened by branches, its general width may be stated at from 38 to 48 feet. It is for the most part separated into three masses, divided by banks of mineral matter, or by part of the matrix destitute of ore.

At Valenciana the vein continues undivided to the depth of 557 feet, and then divides into three branches; and its width, from the floor to the roof, is from 164 to 196 feet. Of these three branches of the vein, there is in general only one which is rich in metals. Sometimes, when these three branches unite, the mine is uncommonly rich. In this celebrated vein there is a certain middle region, which may be considered as a repository of greater riches, for above and below this region the ores are poor in silver.

At Valenciana the rich minerals have been in the greatest abundance, 300 and 1100 feet below the mouth of the gallery.

The labour of the miner is entirely free throughout the whole kingdom of Spain, and no Indian or Meltizoe can be fined to work in the mines. The Mexican miner gains from 1*l.* to 1*l.* 4*s.* sterling *per* week of six days. The men employed in agriculture do not gain more than a third of that sum. The miners work nearly naked, and are searched in the most indelicate manner on leaving the mine. They frequently conceal fragments of native silver and silver-ores in their hair, under their arm-pits, in their mouths, and even in the anus, into which they force cylinders of clay containing the metal. These cylinders are called *longanas*. A register is kept of the silver found in different parts of the

body. In the mine of Valenciana, the value of these stolen minerals, a great part inclosed in the *longanas*, amounted, from the year 1774 to 1787, to 30,000*l.* sterling.

The silver is extracted from its ores in New Spain by amalgamation with mercury, and by smelting: the proportion of silver extracted by mercury is $3\frac{1}{2}$ to 1 of that extracted by smelting; and as fuel is becoming scarce, the quantity of silver extracted by amalgamation increases, the smelting being very imperfectly conducted.

The Mexican miners do not appear to follow any fixed principle in the selection of minerals destined to smelting or amalgamation; for in one district they smelt the same ores, which in another they believe can only be managed with mercury; and it is frequently the abundance or scarcity of mercury which determines the miner in the choice of his method. In general they smelt the argentiferous galena, and the mixed minerals of blende and vitreous copper. The *pacos*, the vitreous, red, and corneous silver-ores, the grey copper-ore rich in silver, and the meagre ores, disseminated in small quantities in the matrix, they find it more profitable to amalgamate.

All the metallic wealth of the Spanish colonies is in the hands of individuals. The government possesses no other mine than that of Huancavelica in Peru, which has been long abandoned. The individual receives from the king a grant of a certain number of *measures*, on the direction of a vein or bed; and they are only held to pay very moderate duties on the minerals extracted. These duties have been valued on the average throughout all Spanish America at $11\frac{1}{2}$ *per cent.* of the silver, and three *per cent.* for the gold. In the space of a hundred years, the annual produce of the Mexican mines has increased from twenty-five to one hundred and ten millions of francs. The produce of the mines in Peru has of late years been rather decreasing, which Humboldt attributes to its being worse governed than Mexico. The process of extraction seems also to be conducted upon worse principles than in New Spain, though in neither of these districts is smelting, or amalgamation, performed with much skill; for, according to M. Humboldt, the quantity of mercury annually consumed in New Spain exceeds two million one hundred thousand pounds troy. The mercury is separated from the amalgam by distillation; but in the whole process, the Mexicans waste eight times more than would be necessary, were the process conducted in the same manner as at Freyberg.

The following table will shew the annual produce of gold and silver in the mines of Europe, northern Asia, and America, as given by M. Humboldt, in kilogrammes. It may be regarded rather as an approximation to the real amount, than as a very accurate statement, the amount of English silver not being included; perhaps this may be estimated at 4000 lbs. troy.

		Gold.	Silver.
Europe	-	1,297	52,676
Northern Asia	-	538	21,709
America	-	17,291	795,581

The kilogramme, it has been before stated, is rather more than 2 lb. 8 oz. troy. It is impossible to value the quantity of gold and silver annually extracted on the whole globe; for we are unacquainted with the amount of what is procured in the interior of Africa, and the central parts of Asia, Tonquin, China, and Japan. The quantity of gold and silver formerly brought by the Dutch from the latter country proves that it is rich in the precious metals. We may draw the same conclusion respecting the northern frontiers of China and other parts of Asia; and the quantity of

gold-dust brought to the western coast of Africa, leads us to believe, that the countries south of the Niger contain large quantities of this metal, though we have little information respecting the silver of the African continent.

Affay and Analysis of Silver-Ores.—Pure native silver requires no other affay than fusion, with a little potash to free it from its earthy matter. In the humid way the silver may be dissolved in nitric acid, and precipitated by common salt. The precipitate may then be fused with soda in a crucible, by which the silver is obtained pure, and the muriate of soda sublimed. The auriferous silver-ores may be treated with potash, by fusion in a crucible: the alloy of silver and gold is first obtained, and the two metals may be separated by the process of parting. See REFINING and ASSAYING.

Those ores which consist of silver combined with antimony or arsenic, or both, are first roasted, to drive off the arsenic and antimony, the silver remaining pure. The process is much facilitated by the use of nitre, for the purpose of oxydating the metals to be dissipated.

The humid analysis of this ore requires more particular treatment.

The ore commonly called arsenical is first to be coarsely powdered, and then distilled vinegar poured upon it, to dissolve the lime of the calcareous spar adhering to it.

A given quantity of the ore so washed is now to be finely powdered, and nitric acid poured upon it: this oxydates the metals, dissolving the greatest part, and leaving a yellowish residuum. To the part dissolved muriate of soda is to be added, which precipitates the silver. This precipitate being washed and dried, will give 77 *per cent.* of pure silver. To the liquid from which the last was precipitated add a solution of potash; a lightish red precipitate is now formed, which, on drying, becomes of a deep brown, and by ignition assumes the form of powder of a whitish-grey colour: this is the arseniate of iron. This substance contains iron and arsenic, in the proportions of 50 to 43 or 44. This is shown by treating the arseniate of iron with charcoal exposed to a red heat; the arsenic is reduced, and sublimes, while the black oxyd of iron remains.

The yellowish residuum left in the first solution is to be digested with muriatic acid: if a white powder remains undissolved, it will be found to be muriate of silver, and must be added to that first obtained. To the muriatic solution add a solution of carbonate of potash, and a yellowish-green precipitate is formed: to this precipitate, when washed and dried, add muriatic acid by a little at once, till the powder is dissolved; add a large quantity of water to this solution, which will produce a white precipitate; this being separated and dried will be pure oxyd of antimony, affording $\frac{1}{4}$ of pure antimony. What remains in solution, after the last substance is separated by the water, may be precipitated by pure potash, and will be found to be oxyd of iron; which, when treated with charcoal, like the first obtained, may be added to the same to make the whole of the iron afforded by the mineral. In this way the arsenical silver-ore afforded, according to Klaproth, the following analysis:

Silver	-	-	12.75
Iron	-	-	44.25
Arsenic	-	-	35
Antimony	-	-	4
			<hr/>
			96
			<hr/>

The sulphuretted ores in the large way sometimes merely require to be roasted to drive off the sulphur: the heat being

urged affords a button of pure silver. This is the case with the variety called *Silver-glance*.

The brittle silver-ore contains a very small portion of antimony and copper. The metallic button obtained by heat will require to be cupelled with lead, in order to get the silver pure; it may, however, be made tolerably pure by treating the button with nitre, by which the base metals are separated.

To effect the humid analysis of brittle silver-ore, the powder is dissolved in dilute nitric acid with a gentle heat. By this treatment a residuum is left equal to $\frac{1}{10}$ of the whole. The solution is to be treated with muriate of soda, like the last.

If the presence of an alkaline sulphate does not form any precipitate with the remaining solution, the mineral does not contain lead: add to the solution an excess of ammonia, and a greyish-white precipitate will be left, which is the oxyd of iron, often containing a little arsenic. If copper be present, ammonia will give to the remaining solution a fine blue colour, and that metal may be separated by a rod of clean iron.

It now remains to examine the first residuum which was unaffected by the nitric acid; this is to be digested with nitro-muriatic acid: the residuum left after this treatment will be found to be pure sulphur. The nitro-muriatic solution is now to be diluted with a large quantity of water; a white precipitate falls down, which, when washed, dried, and ignited, will be found to be oxyd of antimony, of a brown colour.

Klaproth found 100 grains of this ore to yield as follows:

Silver	-	-	-	-	66.5
Antimony	-	-	-	-	10
Iron	-	-	-	-	5
Sulphur	-	-	-	-	12
Copper and arsenic	-	-	-	-	.5
Extraneous matter from the mine	-	-	-	-	1
					<hr/>
					95
					<hr/>

The white silver-ores afford nearly the same ingredients with the last; and the mode of analysis will be similar in the dry way.

The *light-white* and *dark-white* silver-ores contain lead and alumine, and require a different treatment. After the silver is precipitated by common salt, a quantity of muriate of lead is formed at the time, which, on concentration, affords the muriate of lead in bright silky crystals. When these are collected till the liquid will afford no more, a solution of sulphate of soda is to be added, which precipitates the remainder of the lead in the state of sulphate of lead. This powder, being washed and dried, contains $\frac{1}{3}$ ths its weight of metallic lead. The remaining liquid being supersaturated with ammonia, as in the analysis of the brittle silver-ore, a light-brown precipitate is formed: this precipitate is oxyd of iron and alumine. To separate the latter, dissolve the precipitate in nitric acid: separate the iron by prussiat of potash, or prussiat of lime, and afterwards the alumine with soda. The prussiat of iron, heated to a red heat, is decomposed, leaving the black oxyd of iron, which contains $\frac{1}{3}$ of metallic iron.

The first residuum left by the nitric acid, besides antimony and sulphur, which constituted the residuum of the brittle silver-ore, also contains lead. By the frequent addition of muriatic acid with the application of heat, the lead is separated in crystals of muriate of lead; obtaining, by this means, a solution of the muriates of lead and anti-

mony. The residuum is sulphur. The muriatic solution deposits crystals of muriate of lead on cooling. When no more crystals fall down, these crystals are to be added to those obtained before. These, being heated in an assay crucible with twice their weight of black flux, afford metallic lead. This lead, however, treated in the usual way on the cupel, affords a small portion of silver. The solution still contains a small portion of muriate of lead and the antimony. By adding a solution of Glauber's salt, the lead is precipitated in the state of sulphate, affording $\frac{5}{7}$ ths its weight of metallic lead. The antimony, which is the last, may be precipitated by affusion of water. The precipitate, being washed, dried, and ignited, is the pure oxyd of antimony, yielding on its reduction $\frac{2}{3}$ of the metal. The analysis of the light white silver-ore, by Klaproth, gives of

Silver	-	-	-	-	20.4
Lead	-	-	-	-	48.06
Antimony	-	-	-	-	7.88
Iron	-	-	-	-	2.25
Sulphur	-	-	-	-	12.25
Alumine	-	-	-	-	7
Silex	-	-	-	-	0.25
					<hr/> 98.06

The dark silver-ore, by the same, is

Silver	-	-	-	-	9.25
Lead	-	-	-	-	41
Antimony	-	-	-	-	21.5
Iron	-	-	-	-	1.75
Sulphur	-	-	-	-	22
Alumine	-	-	-	-	1
Silex	-	-	-	-	.75
					<hr/> 97.25

The corneous silver-ore, which is muriate of silver, is easily reduced in the dry way by fusing it with soda, in a crucible capable of fusing the metallic silver. The soda takes the muriatic acid, forming muriate of soda, which escapes in white fumes, and the silver is left pure.

In the humid way, it is first fused in a glass retort with carbonate of potash. The mass is then dissolved in hot water, and the solution filtered. The residuum is then dissolved in nitric acid, leaving behind a red powder. This powder, being treated with nitromuriatic acid, leaves behind a small portion of muriate of silver, which must be accounted for in metallic silver, as before directed. Ammonia, being added to the nitromuriatic solution, precipitates a red powder, which is oxyd of iron. To the nitric solution, from the mass first treated with carbonate of potash, muriate of soda is now to be added; which precipitates the silver in the form of muriate, from which the metallic silver may be either calculated, or obtained by fusion with soda. The aqueous solution from the fused mass is now to be saturated with acetic acid. If alumine be present, it will be precipitated. The liquid part is now to be evaporated to dryness. If alcohol be added to the dry mass, it dissolves the acetate of potash. The residuum is then dissolved in water. To this, muriate of barytes is to be added, which, if sulphuric acid be present, will cause a precipitation of sulphate of barytes, the sulphuric acid of which is to be considered as a product of the ore, and will be equal to one-third of the weight of this precipitate, when washed and dried. The remainder of the saline mass

which was dissolved in water may be considered as muriate of potash, the acid of which is another ingredient of the analysis, and will be equal to $\frac{1}{4}$ of the salt.

Physical and Chemical Properties of Silver.—Silver, when pure and newly polished, is of a splendid white colour, and becomes more white when the polish is decadened. Its hardness is nearly that of copper. Its malleability is nearly equal to that of gold. At a heat visibly red in the dark, it can be worked with great facility by the hammer into various articles, in the manner of working iron. After being rolled into very thin sheets, it can be beaten into leaves of $\frac{1}{100,000}$ th of an inch in thickness, and can be drawn into wire finer than a human hair. A wire of $\frac{1}{7}$ th of an inch will require 336 lbs. to break it, when exerted in the direction of its length. At a temperature short of redness, these pieces can be united either by the hammer, or by pressing them together with friction by a steel burnisher.

It melts at the temperature of 28° of Wedgewood, or 4717° of Fahrenheit. If the heat be raised the metal becomes more liquid, and boils. This is occasioned by its assuming the elastic form, in which state it rises, and is condensable on the surface of bodies held over it, as has been observed with gold.

In purifying silver on the cupel, it is observed, that when it is removed from the furnace, and just at the point of congelation, a small explosion ensues, giving to the surface of the button an appearance as if some elastic fluid had been disengaged from it. It has been discovered by Mr. Samuel Lucas, of Sheffield, that the elastic fluid which is separated, producing the phenomenon in question, is pure oxygen gas.

By keeping silver long in a state of fusion, at a very high temperature, it becomes oxydated.

Macquer converted silver into a vitreous oxyd by exposing it to the heat of a porcelain furnace.

Silver is readily inflamed by electricity, and converted into an oxyd of a greenish-yellow colour.

The most direct way to obtain the oxyd of silver is by dissolving the silver in nitric acid, and precipitating it with lime-water. The precipitate is at first white, in which state it may be considered a hydrate of the oxyd. When heated, the water escapes, and it assumes a greenish-yellow colour, inclining to grey. If the heat be raised, the air being excluded, the oxygen is drawn off, leaving the metal in a state of purity: 100 parts of silver have been found to contain 7.5 of oxygen; hence, if the atom of hydrogen be 1, that of silver will be 100. No combination of silver with azote or carbon has as yet been discovered.

It combines with sulphur with great facility: the mere contact of the metal with flour of sulphur is sufficient to give the surface a yellow colour. If the silver be in thin plates, and stratified in a crucible with the same, at a red heat the combination soon takes place, and the mass fuses, forming a sulphuret of silver of a violet colour, sometimes in crystals of the shape of a needle.

This substance is brittle, but sufficiently soft to be cut with a knife. It is decomposable by heat. The sulphur escapes, leaving the metal in a state of purity. This compound is an atom of silver equal to 100, united to an atom of sulphur 15.

Sulphuret of silver is also formed by exposing the metal to sulphuretted hydrogen gas. The small quantity of the latter existing in the atmosphere is capable of soon communicating a yellow, and ultimately a purple colour to polished silver.

Mr. Proust found this tarnishing matter to be a sulphuret of silver. The thinnest coat of gum, or of varnish, completely defends the surface of silver from tarnishing.

Silver combines with phosphorus, forming a phosphuret of silver. This combination is effected by heating in a crucible equal parts of silver and phosphoric glass, with one-fourth their weight of charcoal powder, or, what is better, saw-dust. This compound is of a white colour. It is brittle, but may be cut with a knife. It is, like the sulphuret, decomposable by heat.

Silver combines with several metals, forming alloys. The alloy of silver with gold, when the former is in a very small quantity, is of a much paler colour than gold. These, like all other compounds, are doubtless definite, and hence we should expect, that when these metals combine in the ratio of the weights of their atoms, which will be 100 silver to 140 of gold, the alloy would be the most perfect. And the next perfect would be two atoms of one to one of the other. It is stated by Muschenbroeck, that the hardest alloy of these two metals is with two parts of gold to one of silver.

Silver, as well as rendering gold much paler, gives it a greenish tinge. This alloy is more fusible than gold, and hence is employed as a solder for that metal.

Silver does not form any striking alloy with platinum. Indeed it rather appears to be a mixture than a combination. As is the case with lead and zinc, the two metals separate, when kept some time in a state of fusion. This fact is corroborated by the circumstance, that silver can scarcely be made to unite two pieces of platinum together, when used as a solder, while gold can be employed for that purpose with the greatest success. For the other alloys of silver, see the respective metals.

Salts of Silver.—These consist of the oxyd of silver combined with an acid, some of which only are soluble in water. The presence of the soluble salts of silver is easily detected by muriatic acid, or any soluble saline compound with that acid, by occasioning a dense white precipitate, which soon changes to a purple colour when exposed to the sun's light.

The insoluble salts of silver have the property of coating bright copper with silver, when rubbed upon it with a little moisture. Salts of mercury would give the same white appearance, but this would be distinguished from silver by being capable of dissolution by heat. Salts of silver become black with the hydro-sulphurets of the alkalies. And gallic acid gives a brown precipitate.

Sulphate of Silver.—Sulphuric acid has no action upon silver at the common temperature. When, however, this metal is boiled with the acid, the silver becomes oxydated, sulphurous acid gas is disengaged, and sulphate of silver is formed, which is a white mass, sparingly soluble in water, except an excess of sulphuric acid be present. The latter, on evaporation, affords crystals of a brilliant silvery whiteness, in the form of needles or fine prisms.

This salt is soluble in nitric acid.

When heated, it first fuses, and if the heat be raised, it is decomposed, sulphuric acid and oxygen escaping, leaving the silver in its metallic form.

This salt is decomposed by the alkalies and earths, and all those soluble salts, the acids of which form insoluble compounds with silver. Bergman has stated, that 100 parts of metallic silver, precipitated from nitric acid by sulphuric acid, give 134 of the sulphate. Allowing the 100 of silver to have taken 7 of oxygen, there will remain 28 for the sulphuric acid. This, in 100, will give sulphuric acid 22,

and 78 of oxyd of silver. If this salt be composed of one atom each of acid and base, then, by Dr. Wollaston's scale, the proportions would be 25.5 acid, and 74.5 oxyd of silver. Dalton's numbers would give very nearly the same result.

Sulphate of Silver.—This salt, like the last, is sparingly soluble in water. In other respects, it is but little known.

Nitrate of Silver.—The nitric acid acts with considerable violence on silver, affording red suffocating fumes, occasioned by the copious disengagement of nitric oxyd. If the acid and the silver be pure, the solution becomes clear and colourless, without residuum: if the acid contains muriatic acid, which is often the case with the acid of the shops, then a dense white powder will fall down, which becomes purple in the sun-shine, and is the muriate of silver: if the silver contains gold, a purple powder will be left at the bottom of the vessel: if it contains copper, the solution will be of a green colour, of greater or less intensity, depending upon the quantity of that metal.

The solution of silver affords crystals on evaporation. they are of a prismatic form, but differ in their number of sides; they do not change by exposure to the air, but are very soluble in water. These crystals, when heated, first melt; the heat being raised, the water of crystallization escapes, but the mass still remains liquid: in this state it is frequently cast into moulds, in which it assumes a solid form on cooling. These sticks, which are employed in surgery under the name of *lunar caustic*, are of a grey colour, and when broken exhibit a crystalline appearance.

A more violent heat than that required for its fusion decomposes it, nitrous gas and oxygen being disengaged.

This decomposition is much more rapid when it is heated in contact with inflammable matter. If thrown upon burning coals, it detonates.

If silk, cotton, leather, ivory, and many other bodies, be moistened with nitrate of silver, and the part be afterwards moistened, when a stream of hydrogen gas is applied to it the silver becomes reduced, and appears with its metallic lustre. A stick of phosphorus dipped in nitrate of silver soon becomes coated with metallic silver.

This salt has the property of detonating with sulphur or phosphorus, by being struck smartly with a hammer.

Nitrate of silver is decomposed by all the earths which form salts, and by the alkalies, by combining with the acid. Ammonia, however, does not only precipitate the oxyd, but afterwards combines with it, forming a compound having alarming fulminating properties. The following is the process recommended for its preparation.

From the nitrate of silver precipitate the oxyd by means of lime-water: separate the oxyd, and dry it upon blotting-paper: upon this oxyd pour pure caustic ammonia: let this remain for twelve hours. If a pellicle be formed upon the surface, add a little more ammonia, which will take it up. A black precipitate will be found at the bottom of the vessel, which is the ammoniate of silver, and is the fulminating substance to be obtained. This precipitate is to be carefully collected, and laid in very small quantities upon separate bits of blotting-paper, to dry. When dry, the slightest touch or rubbing motion causes a violent explosion. Those unaccustomed to it should begin with the smallest possible quantities, as serious accidents have happened by exploding it in too large quantities. The liquid part from which the substance was separated will be found to be a solution of the same: if it be heated in a glass retort, a portion of it is decomposed, and the gaseous products disengaged: in a little time, small brilliant crystals of the same substance appear:

these frequently detonate with such violence, as to break the vessel in which they are contained.

The theory of these appearances is obvious: the oxygen of the silver combines with the hydrogen of the ammonia, forming water, which, with the azotic gas of the same, are in an instant rendered to highly elastic by the caloric set free, as to produce the explosive effect so conspicuous in this substance. It is needless to say that the silver is left in the metallic form.

Nitrate of silver is decomposed by all those metals having a superior attraction for oxygen. The oxygen of the silver is given to the decomposing metal, which also combines with the acid. Copper, so employed, precipitates the silver in a white metallic powder, the result being nitrate of copper in the place of nitrate of silver. The precipitate is not pure silver, some copper will always be detected when the precipitate is re-dissolved.

Mercury has also the property of precipitating silver from the nitrate, producing the appearance which has been termed the *arbor Diane*. Lemery recommends one part of silver to be dissolved in nitric acid, and the solution to be then diluted with twenty parts of distilled water: to this add two parts of mercury. The mercury gradually occupies the place of the silver, and the latter is precipitated in the form of vegetation, from which the name has been derived.

The vegetative appearance is caused by the growth of the crystals being from the extreme points of that already formed, as is the case with the growth of vegetables. The mercury, and the smallest portion of precipitated silver, form a Galvanic combination. The silver now in solution is reduced upon that already formed, in consequence of its state of electricity being negative, that of the mercury being relatively positive, by which it attracts the acid. This process would doubtless be facilitated by dropping a small bit of metallic silver upon the mercury, added to nitrate of silver. This would form a Galvanic combination, and the bit of silver would become an immediate rallying point for the silver in solution. If a little of a dilute solution of nitrate of silver be spread upon a pane of glass laid in an horizontal position, and a common pin be laid in the middle of the covered part, in a few hours, beautiful ramifications of silver extend from every side of the pin; sometimes to the distance of an inch. This is also to be explained by Galvanism.

Muriate of Silver.—When muriatic acid, or any soluble muriate, is added to nitrate of silver, a dense and blueish-white precipitate is thrown down, which is muriate of silver. Although white when it is just precipitated, it soon assumes a purple tint by exposure to the light, and the change is quicker as the light is more intense: hence this substance has been employed to measure the degree of intensity of light, by the time in which the change of colour takes place.

It may be said to be insoluble in water: this property, and its conspicuous appearance in other respects, renders the nitrate or sulphate of silver so valuable as a test for muriatic acid. The latter, on combining with the silver, forms the salt in question.

When this salt is exposed to heat, it easily melts: on cooling, it becomes solid. It is a semi-transparent mass, of a grey colour, and of a horny appearance, from which it has been called *luna cornea*, or horn-silver. If fused with a great heat in a crucible, it becomes so thin a fluid as to sink through the pores of the crucible. It is not decomposed by any of the acids, nor the alkalies, but when heated with the carbonates of potash or soda, the acid is disengaged. It dissolves in caustic ammonia, forming a transparent solution: this, by exposure to the air, undergoes considerable change. A pellicle forms on the surface, which is first of a blueish colour,

and ultimately black. This pellicle, on examination, is found to be muriate of ammonia and reduced silver. Those who with Sir Humphrey Davy hold oxymuriatic acid to be a simple body under the name of chlorine, consider this substance as a compound of the latter substance with metallic silver. Sir Humphrey gives it the name of *argentane*, and Dr. Thomson, more consistently, *chloride of silver*.

The composition of this salt, according to Proust, is

Muriatic acid	-	18
Oxyd of silver	-	82

By the atonic theory it should be constituted by 100 + 7.5 = 107.5 of oxyd of silver, and 24 muriatic acid, which would give

Oxyd of silver	-	81.7
Muriatic acid	-	18.3

Sir Humphrey considers it as a compound of one proportion of chlorine, 67, and one proportion of silver, 205, which will give

Silver	-	-	75.3
Chlorine	-	-	24.7

Considering the 24.7 of chlorine as oxymuriatic acid, which would be 18.8 muriatic acid, and 5.9 oxygen; then giving this oxygen to 75.3 of silver, would give 81.2 of oxyd of silver, and 18.8 of muriatic acid in the 100, which nearly agrees with the above. The property which this salt has of becoming black by the action of light, has rendered it useful for marking linen. Very improper ingredients have been sold for this purpose. The nitrate of silver is employed to write with upon the linen, which is very proper; but the part is often prepared by a solution of soda or potash, instead of a solution of muriate of soda (common salt). The following will be a recipe which cannot fail of success: dissolve 30 grains of lunar caustic in one ounce of distilled water; this will be for the writing liquid. For the preparing liquor, dissolve half an ounce of common salt in four ounces of water; and in the same dissolve half an ounce of gum arabic. Moisten the part to be marked with the latter, and dry it till the writing will not run. The letters will first appear of a blueish-white, but become perfectly black by exposure to light.

The fluete, borate, phosphate, carbonate, and arseniate of silver, are insoluble powders, having no striking properties, or but little known. The arseniate is formed by adding arseniate of potash to any soluble salt of silver. It falls down in the form of powder of a yellow colour. Its insolubility, and its conspicuous colour, have been taken advantage of by employing nitrate of silver as a test for arsenic.

The chromate of silver is an insoluble salt, of a red colour; it is formed by adding chromate of potash to nitrate of silver. It, however, becomes purple by exposure to air and light.

Acetate of silver is a soluble salt, formed by adding the acetic acid to oxyd of silver. The solution affords prismatic crystals.

The rest of the salts are but little known.

SILVER, in *Medicine*, is called *luna*, the moon; and has been much extolled for its virtues by chemical writers. But

crude silver, however comminuted or attenuated, has not been observed to produce any medical effect. It is not soluble in any of the fluids of the animal or vegetable kingdom.

Several preparations have been made from silver; particularly a

SILVER Pill, or *Pilula Lunaris*, which is a chemical preparation of silver, formerly highly commended as an anthelmintic, and as a purgative remedy for dropries, and in many other inveterate ulcerous diseases.

The method of making it is this: dissolve an ounce of pure nitre in distilled water; then dissolve an ounce of crystals of silver, made in the common way, with pure silver and aqua fortis, in three times the weight of water, so that the solution may be perfectly limpid: mix the two solutions together, they will become a clear homogeneous liquor; evaporate this to a pellicle, and crystals resembling nitre will shoot; pour off the remaining nitre as before, and the remaining nitre will shoot with the silver, in form of crystals, again, upon a second evaporation: let these crystals be dried upon a paper, and then placed in a glass vessel in a very gentle heat, enough to make them smoke, but not run; stir it with a piece of glass all the time, and keep it over the fire, till no more fumes arise; thus the acid spirits will be driven off, and the silver remain of a very bitter taste and purging quality. It must be kept in a dry close vessel.

This discovery has been made to serve to many other purposes, besides its uses in medicine, and has furnished the dishonest pretenders to alchemy with one of their most cunning methods of deceit. They have been able, by this means, to conceal silver in nitre, and that in a very large proportion, as in one-tenth part of the whole quantity; and this nitre being projected in an equal quantity on melted lead, gives an increase of one-tenth part in silver, which remaining upon the test, will deceive the ignorant, as if a tenth part of the lead were converted into pure silver. People who are upon their guard, may, however, discover the cheat, by dissolving the pretended nitre in ten times its weight of water, and putting a polished plate of copper into the solution; for

every particle of the silver will then be precipitated out of the liquor upon the copper, and to the bottom of the vessel.

The medicinal use is this: the dried mass, consisting of the salts of silver and nitre, is to be reduced to a fine powder: this powder, applied to ulcers, acts in the manner of the lapis infernalis, or silver-caustic, only much milder: but for internal use, the quantity of two grains of it is to be ground to a fine powder, with six grains of loaf-sugar, in a glass mortar; this is to be then mixed with ten grains of the crumb of bread, and formed into nine pills: these are to be taken by a grown person upon an empty stomach, drinking after them four or six ounces of hot water, sweetened with honey. It purges gently, and brings away a liquid matter like water, often unperceived by the patient. It is said to kill worms, and perform great things in many obstinate ulcerous disorders. It purges without griping, but it must not be used too freely, nor in too large a dose, for it always proves weakening, and in some degree corrosive on the stomach; but this inconvenience is greatly alleviated by rob of juniper. Boerh. Chem. part ii. p. 297.

However, with this assistance, it is at best a dangerous medicine, and as such is deservedly excluded from practice. Lewis.

SILVER, Tincture of, is made by dissolving thin silver plates, or silver shot, in spirit of nitre; and pouring the solution into another vessel full of salt-water. By this means, the silver is immediately precipitated in a very white powder, which they wash several times in spring water. This powder they put into a matras; and pour rectified spirit of wine, and volatile salt of urine, upon it. The whole is left to digest in a moderate heat for fifteen days; during which, the spirit of wine assumes a beautiful sky-blue colour, and becomes an ingredient in several medicines. This is also called *potable silver*, *argentum potabile*.

Silver is likewise converted into crystals, by means of the same spirit of nitre; and this is called *vitriol of silver*.

The lapis infernalis argenteus is nothing but the crystals of silver melted with a gentle heat in a crucible; and then poured into iron moulds. See CAUSTIC, *Lunar*.

Addenda and corrigenda

PRINTING, *CALICO*, is the art of imparting various colours to plain calicoes, in any form, or according to any pattern that may be desired, by means of certain colourless mordants previously applied to the cloth. This art has sometimes been denominated *topical* dyeing, and the various branches of it are calculated to astonish those who may have the opportunity of witnessing the different processes, without being acquainted with the nature of chemical mordants, and their several uses in the arts.

The art of calico-printing is of great antiquity. Homer speaks of the variegated cloths of Sidon, as having a very splendid appearance; and Pliny describes the Egyptians as accustomed to prepare parti-coloured linens, and observes that these colours were produced after a manner corresponding with our method of topical dyeing. He says the Egyptians began by painting or drawing on white cloths, (doubtless linen or cotton,) with certain drugs, which in themselves possessed no colour, but had the property of attracting or absorbing colouring matters. After which, these cloths were immersed in a heated dyeing liquor; and though they were colourless before, and though this dyeing liquor was of one uniform colour, yet when the cloths were taken out of it soon after, they were found to be wonderfully tinged of *different* colours, according to the different natures of the several drugs, which had been applied to their different parts; and these colours, so wonderfully produced from a tincture of only *one* colour, could not afterwards be discharged by washing; and he considers it as admirable, that the dyeing liquor, which, if cloths of different colours had been put into it, would have confounded them all, should thus produce, and permanently fix *several* colours, being itself only of one colour. Pliny, lib. xxxv. cap. 2.

This account contains so plain a description of one of the branches of calico-printing, that no one who is conversant with the present practices can entertain any doubt but that the ancient Egyptians were acquainted with many of the principles of this very curious art. Our readers, who are desirous of further investigating this interesting subject, will find abundant and satisfactory information by consulting the following works: viz. Pliny's "Natural History;" the 26th volume of "Recueil des Lettres Edifiantes, &c." Strabo, lib. xv.; Delaval's "Experimental Inquiry into the Cause of Change of Colours, in opaque and coloured Bodies;" Berthollet's "Elements of the Art of Dyeing," vol. i. p. 28; Beckman's "History of Inventions," in 4 vols. 8vo.; Mr. Parkes's "Chemical Essays," vol. ii. p. 65, &c.; and Dr. Bancroft "On Permanent Colours." In the above works, abundant testimonies will be found to shew that printed calicoes were not unknown to the ancients;

and we have good reason also to suppose that the colours which they imparted to their cloths possessed a considerable degree of permanency, as we know that iron and alum were both employed by them as mordants. It is likewise well known that several ancient nations were acquainted with soda, madder, tin, the juice of the *laccinum*, cochineal (or an insect similar to it), the celebrated Tyrian purple, and other materials, sufficient in the whole to enable them to give a great variety of colours and tints to their several productions.

Our object, however, in this communication, is to give a succinct account of the art of calico-printing as it is conducted at present, and we do not know that we can do better than to copy the greater part of the detail which has been given by Mr. Parkes in his "Essay on Calico-Printing," in the second volume of his "Chemical Essays," and which he has very politely allowed us to make use of in any way we think proper.

From this essay it appears, that calico-printing, as an art, is but of modern date in this country, though it has been practised in India, and other parts of the East, from time immemorial. From various accounts it appears, that formerly in India the cotton cloths when brought from the weavers, partly bleached, were worn next to the skin by the dyer and by all his family, during the space of eight or ten days, after which they underwent several macerations in water, with goat's dung, and were afterwards submitted to frequent washings, and as frequent dryings in the rays of an intense sun-shine. Afterwards they were soaked for some time in the mixture of the astringent fruit of the yellow *myrobalans*, and of curdled buffalo's milk. When thoroughly impregnated therewith, they were squeezed, dried by exposure to the sun, and then, by pressure and friction, they were made smooth enough for being drawn upon by the pencil with the different mordants.

The first of these mordants was an iron liquor, made by dissolving iron in a mixture of sour palm-wine and of water in which rice had been boiled. This liquor was applied to the figures or spots intended to become black, and afterwards the aluminous mordant was applied, commonly by children, with the pencil, to the parts intended to be made red. The pieces were then exposed to the hottest sun-shine, that the parts to which the mordants had been applied might be dried as much as possible: and then they were thoroughly soaked in pits of water, to cleanse them from the superfluous mordants, as well as from the buffalo's milk, &c.: and lastly, they were dyed in water, with certain roots answering nearly in their effects to those of madder.

It was in this way the manufacture of printed cottons

was conducted by the Indians in *former* times. The following is an account of the *modern* Indian practice, in one particular branch of their manufacture, which Mr. Parkes says he procured from a gentleman who had spent some time in India, and who had taken pains to inquire into their manipulations.

This process relates to the method of printing the fine cotton chintz counterpanes, which the natives call *pallampoor*s, and which are manufactured at Madras. These are woven in one piece, from two to four yards square, and are printed, or rather painted, with various designs, and in various colours. Their method is to draw a pattern first on sheets of paper sewn together, of the size of the intended pallampoor; and then to prick out the same in the paper with a sharp instrument. This done, the paper pattern is smoothly fixed upon the cloth, which is previously dampened, and a small muslin bag containing some kind of black powder is rubbed over the whole, in order to pass a part of the powder through the pin-holes, and completely mark out the pattern.

The pattern being thus sketched upon the cloth, the paper is removed; and when the outline of the various figures is drawn with a pencil, the piece is considered to be ready for receiving the colours.

One colour is then laid on with a brush made with a tough root of a particular kind of tree, or with the husk of the cocoa-nut; and when this is dry, the piece of cotton is given to a woman to wear, or to use in the family, till it be very much dirtied; in order that it might necessarily undergo a thorough washing, which is thought requisite to prove the goodness and permanency of the colour. Another colour is then laid on in the same manner, and the piece is again submitted to the same trial of wearing and washing. The Asiatics may not be aware of it; but doubtless the long exposure to the air in these cases is the important point, as it is well known that the atmosphere is a prime agent in rendering many colours permanent, which, under a different treatment, would be heavy and fugitive. This is repeated for every colour that is employed;—and when any one of these colours is found to be deteriorated by this treatment, it is printed afresh; and so are all the rest, till the workman is satisfied that all the colours are actually permanent.

This tedious process is adopted, however, only when the manufacturer means to warrant the article; but in all cases, even in those pieces which will not bear washing, the colours are laid on by a brush, as before mentioned.

Whether they are all substantive colours which are thus applied, or whether they use any species of mordants in their fast work, we are unacquainted, as the artists of India observe great secrecy, and are extremely jealous on this subject.

Such are the facts which we have been able to collect respecting the progress of calico-printing from the earliest ages; and also of the present state of the art among the Asiatics. The more difficult part now remains, *viz.* to give a brief detail of the most important processes of our own artists. This, however, we shall endeavour to do with the utmost plainness, and shall not fail to suggest any improvement that may have occurred to us during our inquiries respecting this very interesting and varied branch of manufacture.

We have not been able to ascertain when calico-printing was introduced into this country, though there are various reasons for believing that it is an art, among us at least, but of modern date.

As the whole of this ingenious business, as it is now

conducted, depends upon the proper application of a few compounds called *mordants*, it will be necessary, in the first place, to explain their nature and uses. In doing this, one or two preliminary remarks will assist us.

The colouring substances chiefly employed in this art are divided into two classes, *viz.* *substantive* and *adjective*. A *substantive* colour is one which is capable of itself of producing a permanent dye on wool or woollen cloth; such is the juice of the buccinum, used by the ancients for producing the imperial purple; such are also the woad and indigo employed by the moderns for producing a permanent blue; and we may add the metallic solutions, particularly those of iron, cobalt, gold, platina, and silver, which give various colours, according to the processes by which they are prepared.

It has been proposed to employ this valuable permanent colour for pencilling on fine muslins. In time of peace it might readily be procured in sufficient quantities, and would prove an important addition to the resources of the British calico-printer.

Dr. Bancroft tells us, that the first mention of indigo, as known in England, is in the Act of the 23d of queen Elizabeth, chap. 9, where it is called *Ancle*, or *Blue Inde*. Bancroft on Permanent Colours, p. 138.

By *adjective* colours are meant all those which are incapable of giving permanent dyes without the aid of certain intermedia, which form as it were a bond of union between them and the substances intended to be dyed.

These intermedia are what are known by the term *mordants*, and are used for this purpose in very considerable quantities by the calico-printer of the present day.

Several expedients of this kind were employed by the ancients to produce fast, or, more properly, permanent colours, and this appears from the testimony of Aristotle and Pliny. The chief articles in use at present are, the acetate of iron, the acetate of alumine, and the various solutions of tin, all of which should be very carefully and correctly prepared.

We have already given some account of chemical mordants in vol. xxiv. part 1, under the article *MORDANTS*; which see.

When piece-goods are designed to be dyed of one uniform adjective colour, they are first immersed in a solution of one of these mordants, then hung up to dry, and to absorb the oxygen of the atmosphere. When sufficiently exposed to the air, they are washed or dinged, to remove the superfluous mordant; that is to say, that part of it which is not chemically combined with the cloth; and the goods are then submitted to a bath of that particular kind of colouring matter which is to be imparted to them.

The dung of the cow is used in such large quantities by the calico-printer, that it has become an article of great expence. The proportion that is employed is usually about one bushel to one hundred gallons of water, though frequently a larger proportion would be more effectual. The brightness of the colours, and the purity of the whites, are always dependent upon the quantity of the dung employed.

Whenever it is meant that the colour should be partially inserted, the mordant is applied to those particular parts only; so that, when the piece is immersed in the colouring bath, no other place will receive the permanent stain. If a sufficient number of colouring substances should ever be discovered, that have no affinity for any thing but the chemical mordants, the business of calico-printing would be rendered much more easy and simple than it is at present. For though the whole texture of the cloth will be coloured,

yet having in itself no affinity with the vegetable with which the decoction is impregnated, the whole of the colouring matter will be easily removed by exposure to the air, and the ground of the piece restored to its original whiteness; while those parts to which the mordant was applied, will retain and fix the colours in a way which will be more fully explained hereafter.

Formerly all calico-printers were bleachers; but in the neighbourhood of London there are separate and distinct trades, and the printer either purchases bleached goods for printing on his own private account, or receives the cloth from his customers in a white state; and, when printed, he returns the identical pieces, and is paid so much *per* yard, according to the number of colours, for printing them.

In our opinion every printer should bleach his own goods, for it is impossible always to rely with confidence on the care of those who bleach for hire; and every printer knows that good bleaching is absolutely a necessary preliminary in the production of good printing. Indeed, this is now pretty generally acknowledged in the north of England; for most of the opulent houses in Lancashire and in Scotland, which produce fine work, are bleachers as well as printers.

Oxymuriate of lime is the agent generally employed in bleaching; but it appears to us that some other article might be introduced with advantage. For, as the goods are washed in diluted sulphuric acid when they are taken from the oxymuriate of lime, a sulphate of lime is always formed, which becomes fixed in the fabric, and, acting as a mordant when the pieces come into the madder-copper, occasions an indehble stain, which in very fine goods often impairs their beauty. If oxymuriate of soda were employed, the sulphuric acid would form a soluble salt with the soda, easily removable by washing.

No people have taken more pains to excel in bleaching than the Irish, and their credit is established accordingly. The German linen, we believe, is generally better than theirs; but the Irish has always the preference in foreign markets, owing to their superiority in bleaching and finishing.

A very minute account of the various processes in bleaching has been already given in our 4th vol. part ii. under the article BLEACHING; which see.

By whatever means the bleaching is performed, the printer commences his part of the business in the following manner.

The goods are first *dressed* by singeing off the whole of the nap which is attached to them. This is effected by the following contrivance:—Ten pieces are generally wired together, and wound upon a roller, from whence they are passed over a hot iron, nearly in the form of half a cylinder, and received upon another roller; from thence they are returned to the iron, which is still kept red, or nearly at a white heat. The use of repeating this process is to remove the nap more effectually than it would be done by passing it only once over.

The next operation is that of *sleeping*, which consists merely in soaking the pieces for twenty-four hours in a vessel of weak alkaline ley, at a temperature of about 100°. These operations of singeing and sleeping are going on at one and the same time, which effectually prevent any accident that might otherwise arise from the effects of the hot iron.

The goods are then boiled or else bowked in a solution of potash (some workmen prefer to have this alkali in a pure caustic state); they are then well cleaned by thorough washing in wash-wheels, or in stocks, to ensure their being entirely divested of the alkali. The intention of thus treating them with potash, is to remove any grease or im-

purity that may be attached to them, which would otherwise endanger the evenness and uniformity of the colours. This process is called *gbing*.

By some observant calico-printers it has been imagined, that the rendering of the ley caustic is apt to impair the texture of the cloth; and we doubt not but that this has often been the case. Under the eye of the master, however, we are sure that it might be employed with advantage and safety.

It may be remarked, that in weaving calicoes the workman generally greases the reeds, in order to make them move easier. Tallow is also employed for dressing the warp, and this has a baneful effect on all goods which are designed for printing. Wherever this grease is in the cloth, it becomes fixed by the operation of singeing; and if it be not taken out before bleaching, it will not come out afterwards by the usual process of affing and furring; for, when the pieces are submitted to a blue vat to be dyed of a uniform self-colour, all those greasy places will be found to have taken the dye in a very imperfect manner. If the calico-manufacturers themselves would make a point of preparing the oleaginous matter for the weavers, and would furnish them with nothing but pure vegetable oils, such as those of rape, linseed, &c., it is very likely that these inconveniences would not occur; for the stain from *vegetable* is not so indelible as that from *animal* oil. To cleanse such goods, various expedients have been adopted, but we apprehend nothing but a solution of caustic alkali can be depended upon. To prove the effect of any method which may be tried, it is a good way to run the pieces through water, and then to pass them from the water so gradually over a roller, as to give the superintendent an opportunity of examining every inch of the surface; and if any part remains greasy, it will be seen at once, for that part will continue dry, while all the rest of the cloth is wet.

There is another way in which the goodness of bleaching might be proved. Let a few of the suspected pieces be run once or twice through a madder-copper, at the temperature of about 180°. This will inevitably mark any part that may be imperfectly bleached; whereas, if the operation has been properly performed, they will come out so little stained, that an intelligent workman, who has been used to a madder-copper, will at once be satisfied that they contain no impurity that can form a permanent mordant.

The next process is one with diluted sulphuric acid. A quantity of soft water having been poured into a leaden vessel, oil of vitriol is gradually added to it, in the proportion of about twenty pounds of oil of vitriol to every hundred gallons of water, which by weight is in the proportion of about one to forty.

When this mixture has been well stirred, it is ready for use. Sometimes it is employed in this state, at others it is heated to 90° or upwards of Fahrenheit, according to the nature of the work to be done, and the goods are immersed in it. They are not suffered to lie in this solution, but are wound by means of a winch over a wooden cylinder, that every part of the cloth may be immersed in the fluid, and exposed alternately to the action of the atmosphere.

This operation is generally continued for about twenty minutes, and is designed to remove any iron-moulds or other stains which the cloth may have acquired. It has also the effect of neutralizing any portion of potash that may have been left in contact with the cloth. The process is called *furring*.

After this operation it is necessary to wash the goods thoroughly, that no part of the acid may be left in them to injure their texture, and this is best effected by means of

the wash-wheel. The calicoes are then to be regularly and thoroughly dried, which finishes these preliminary operations, known in the trade by the term *preparation*; so that those cloths which have passed through these manipulations are said to have undergone a preparation. Besides the uses already mentioned, there is another advantage attending these processes, *viz.* that the cloth which has undergone this preparation will bleach sooner, the colours will be brighter, and the whites more delicate, than they would have been had they not gone through these previous operations.

The next process is that of *calendering*. Here the goods are passed through a set of rollers, which gives them a gloss, and the appearance of their having been ironed. They are now fit for printing. For copper-plate printing, or cylinder work, the process of calendering is omitted.

In printing fast colours, the artist usually proceeds in this way: he lays the piece of calico, which has been already smoothed by calendering, upon a strong thick table, which is previously covered with a woollen cloth. He then proceeds to apply one or more mordants, as the case may require, for fixing the intended colours. These mordants are applied by means of wooden blocks, with the patterns formed upon them. These blocks were formerly chosen of holly, and the cutting them was a separate branch of the business, and was called *block-cutting*. Of late years, however, a considerable improvement has been made in this part of the business by the introduction of brass or copper; that is, the pattern, instead of being actually cut in the wood, is now formed by means of slender pieces of one of those metals being firmly fixed to the block, so as to produce the pattern intended. This alteration was occasioned by the perishable nature of wood, on account of which every printer incurred great and unnecessary expence. The pattern when thus formed with copper, is not only more lasting, but it has also the advantage of giving greater sharpness and beauty to the impression. When it was customary to use wooden blocks, the patterns were not encafed in the wood, but the wood was cut away in such a manner as to leave the pattern in relief. It will be obvious that this must always be the case in *block-printing*.

When the mordant is ready, it is mixed up either with flour-paste, or with a thick aqueous solution of gum arabic, gum senegal, or gum tragacanth, and is then spread upon a piece of superfine woollen cloth, strained tight upon a hoop. This is placed within another hoop, covered either with sheep-skin or oil-cloth. These hoops are both so broad as to give to each of them the appearance of a tambarine. That which is covered with the woollen cloth is called a *sieve*, the other a *case*. The sieve within its case is now placed in a small tub of gum-water, and is ready for use.

Flour is an article of considerable consumption with the printers for making paste. Some houses buy twenty barrels of American flour at once. Should it be musty or sour from keeping, it is of little consequence for their use; but they are careful to buy none but such as has been made with sound wheat, for if unsound it will be of no value for their purposes.

Gum tragacanth is much dearer than the other gums mentioned above; but notwithstanding this, it must be had for some styles of work, as no other will answer for any of those colours or mordants which are prepared with nitrous acid. A solution of gum senegal would be coagulated in an instant by any of those preparations. Of late years, an article called British gum has also been much in use for the same purpose; so much so that the making of it has become a distinct trade. It is merely common starch pul-

verized, and then calcined till it assumes a cinnamon-brown colour.

When the apparatus is thus prepared, the mordant is applied by a brush to the surface of the sieve. This is called *teering*.

It should have been remarked, that when a colourless mordant, like the acetate of alumine, is employed, the workman generally mixes a little of the decoction of Brazil wood, or of any other fugitive dye, with it. This is called *fightening*; and is for the purpose of making the pattern more obvious to the workman, that he may see its progress, and the efficacy of the materials, as he proceeds in printing. The manipulation may be thus described.

Taking the block containing the pattern in one hand, the workman applies it gently to the surface of the sieve, so that a sufficient quantity of the thickened mordant may adhere to the figures. When the block is thus charged, he applies it to the calico, and gives it a blow with a small mallet, either slightly or otherwise, according to the nature of the pattern.

This alternate application of the block to the sieve and to the calico, is continued till the workman has gone over the whole piece. In this way, several different mordants are sometimes applied to the same piece of goods. This is indeed always necessary, when the finished piece is intended to contain a variety of colours, the different colours requiring different mordants to fix them and render them permanent.

The calico is now removed to a room called the *stove*, where a certain degree of heat is given to it by means of flues, which go round the room on the inside, near the floor. In this room, it is generally continued for at least twenty-four hours. This is when common red-liquor has alone been printed; but if citric acid or strong muriate of tin has been employed, less time is sufficient, and for the latter seldom more than half an hour is allowed. The intention of this is to evaporate the acids used in the preparation of the mordants, and which might otherwise injure the texture, and also to fix the base more surely within the fibres of the cloth.

In this operation, an attention to temperature is of the utmost importance. In general the room is kept at about 90°; but an intelligent calico-printer varies this according to the nature of the work under operation. If iron-liquor has been employed in printing the goods, it is an excellent practice to keep them for several days exposed to the atmosphere, after their removal from the stove, as the blacks, pompadours, olives, and indeed every other colour prepared with that metal, will increase in intensity; the goods will clean better in the dung-vessels, as will be explained hereafter, and the colours will rise higher and brighter when they come into the copper of bark or madder. The iron in an acetous solution is in the state of the *black* oxyd; but by exposure to the air it acquires a further dose of oxygen, and the more nearly it is made to approach to the state of the *red* or peroxyd, the more fit it becomes for a mordant in dyeing. It may be worth an experiment to discover whether the colours containing iron would not be better if they were suffered to be only a *very short time* in the stove, but were hung up instead for several days, exposed to a current of air at the temperature of the atmosphere; as the iron would thus acquire the oxygen slower, and consequently would be fixed more firmly within the cloth.

When the pieces have been properly stoved, they are passed, by means of a winch, through water at various temperatures, with a little cow-dung mixed in it. This

part of the business was formerly conducted in a very cleanly and negligent way; but of late years some printers have incurred a considerable expence in the construction of their dunging machines, with cocks for hot and cold water attached to them, and thermometers to regulate the temperature. Those erected by Mr. Wright, a very ingenious calico-printer, at Strines, near Disley, are the most complete of any we have yet seen.

The intention of the dung is to absorb and remove that portion of the mordant which is not actually combined with the cloth, and which otherwise might stain the white or unprinted parts.

We suspect the dung of the cow is serviceable in another way besides that of cleansing, though the printer may not be aware of the nature of its operation. To clean calicoes by immersion in a dung-vessel, may appear to be a strange phrase; but as this is the technical language of the trade, no other could be employed with propriety. It is acknowledged that madder, cochineal, and some other dyes, produce much better colours on woollen than on cotton cloths, owing to the former being of animal, and the latter of vegetable origin. We presume, therefore, that the dung imparts an animal matter to the fibres of the cotton, and that this animal matter acts as an additional mordant, and thus more powerfully attracts the colouring particles of the dye, than the mordants alone would be capable of doing. Berthollet, who analysed the dung of the cow, found in it a substance partaking of the nature of bile.

If a piece of calico, prepared with the acetate of alumine, be divided into two parts, and the superfluous mordant removed from one of them by cow-dung and water, and from the other by water only, though both fluids were at the same temperature, it will be found, on passing the two portions through a decoction of weld or quercitron bark, that the yellow will be much more intense and bright in that which had been submitted to the action of the cow-dung. This is a satisfactory and decisive experiment.

The process of *lunging* is an operation that varies in time from five to forty minutes, according to the style of work. The pieces are then taken to the river or wheel, to be more effectually washed; after this they are passed through tepid water, in order that the workman may be assured that every impurity is removed.

His next care is to provide a copper boiler of pure cold water, in which a sufficient quantity of madder is put, and a fire lighted underneath it. The calicoes, printed and rinsed as above, are now put into this boiler, and from the time they are immersed, the workman never ceases to turn the winch, so as to pass every part of the goods repeatedly through the liquor, till the whole acquires a boiling heat. Indeed, this operation is sometimes continued for ten or fifteen minutes after the bath of madder actually boils, when the pieces are taken out and washed.

Madder is one of the most valuable drugs we have, for a variety of purposes in dyeing and calico-printing; as it is the agent by which the best and most permanent blacks are produced; also the finest purples, and every shade of red from a pale pink to a crimson. But perhaps it may not be generally known that this article improves by age. If a quantity of madder-roots be ground, and then packed tight in a cask, so as to exclude the air, and are kept thus for six months, they will then dye a much better colour, and go much further than they otherwise would have done, had these roots been used as soon as they were ground.

This process, which is called *maddering*, has the effect of imparting all the requisite colours to the goods, by means of one operation, which may be thus explained. While one

mordant precipitates the colouring matter of the madder to a red, another precipitates a different portion of it to a purple, another precipitates it to a black colour, and so of every possible shade, from a lilac to a black, and from a pink to a deep red.

If a portion of weld or bark be added to the madder, every shade from a brown to an orange may be produced; whereas, if weld or bark alone be employed, all colours between a dark olive and a bright lemon can be imparted to the cloth. These changes are all occasioned by the play of chemical affinities, and are due to the improved state of chemical knowledge.

Here it may be worth remarking, that whenever it is of consequence to produce the finest yellows or more delicate lemon colour, it is necessary to dry the pieces in the open air, as the stove would not fail to injure such colours; for stove-drying has always a tendency to convert a yellow to an orange. It is also necessary to be equally careful in the operation of dunging the mordants for these pale yellows; for, should this be done at a higher temperature than 96° or 100° , their beauty will certainly be impaired. There is another advantage in this, *viz.* by dunging at this low temperature, the dyeing may be completed even at 110° or thereabouts, which will give a much livelier colour than where a higher temperature has been employed.

The mordants generally used in calico-printing are acetate of iron for browns, blacks, lilacs, &c. and acetate of alumine for all the different shades of reds and yellows.

Formerly the acetate of iron was made by digesting old iron hoops in sour beer, or in very weak vinegar; but of late years it has chiefly been made with the pyroligneous acid, [if wood be submitted to an intense heat, when inclosed in an iron vessel of any kind with a proper aperture to allow the vapour to pass, this vapour on being condensed forms the acid in question, and is now known to be a kind of impure vinegar. The wood in this case is converted into charcoal, of which a great deal is prepared by this process, particularly for the formation of gunpowder,] the oleaginous impurities of which tend, in some cases, to improve the mordant.

Blacks are also produced by the nitrate of iron [nitrate of iron was not applied to calico-printing till within the last fifty years. This discovery formed an important era in the trade, as it afforded the manufacturer the means of varying his styles of work in a multiplicity of ways and forms, which, till then, were entirely unknown,] and gallic acid; the mixture is called chemical black. This nitrate of iron is made by dissolving metallic iron in a peculiar kind of aqua-fortis. Common aqua-fortis will not answer for this purpose; for, though it may dissolve the iron with rapidity, part of the metal is apt very soon to precipitate; which not only weakens the colour, but leaves the remainder so acidulous, that there is always a danger of such a preparation injuring the texture of the cloth.

It is, however, necessary to remark, that the black which is formed by this solution of iron, is produced in a different way from blacks in general; for, when common iron-liquor is used for this purpose, it is first printed on the calico: and when it has been sufficiently oxydized by exposure to the air, the goods are boiled in a decoction of madder, which renders such parts as had been printed with the acetate of iron an intense black. But the black from nitrate of iron and galls is applied at once to the cloth, and is not afterwards raised by dyeing.

The calico-printer by using a black ready formed is thus enabled to mix it with other colours, in cases where by dyeing alone it could not be produced, as in conjunction with yellows and olives, raised by weld or quercitron bark.

The acetate of alumine is prepared by a mixture of the sulphate of alumine with acetate of lead, both in a state of solution; so that, on the theory of double decomposition, sulphate of lead is formed, which precipitates, while the acetate of alumine remains in solution.

Since the demand for this article has been increased on account of the extension of the printing trade, it has been prepared from the pyroligneous acid by means of lime and alum. The following is the method:

The pyroligneous acid is first passed through a still, to divest it of a portion of the tar which is always dissolved in it; it is then saturated with lime or whiting; and lastly, the acetate of lime thus formed is decomposed by a heated solution of sulphate of alumine. The result of this double decomposition is sulphate of lime, which precipitates, and acetate of alumine, which is drawn from the sediment of the calcareous sulphate, and preserved for use.

And here it may be necessary to caution the manufacturer against a misfortune that may befall him if he be not conversant with the chemical nature of the substances he employs.

Magnesian lime-stone abounds in Derbyshire, and in some of the adjacent counties; and should a maker of acetate of alumine employ such lime in his process, the article which it would produce would in all probability be entirely unfit for the use of the calico-printer. But we must be more explicit.

In employing the common lime in conjunction with alum, a sulphate of lime will be formed, as mentioned above, and this being nearly an *insoluble* salt, will precipitate. But here, sulphate of magnesia would also be formed, which being a *soluble* salt, would remain in solution, and increase the specific gravity of the liquor, a circumstance which would be very apt to occasion the deception which we are anxious should be avoided. If magnesian lime-stone be employed, the liquor will appear good by the hydrometer; but, as it will contain more Epsom salt than acetate of alumine, it will be unfit for every purpose for which it was intended.

While speaking of acetate of alumine, we cannot avoid remarking that the process which has just been described for making this mordant, and which is followed invariably by many of the manufacturers in the North, is extremely improper, on account of the lime which is employed in it, be the lime ever so good, as that earth is very prejudicial to every species of red dye. The true way of making it, though more expensive, is that which was originally pointed out by Berthollet, and which consists in decomposing sulphate of alumine by means of saccharum saturni, or acetate of lead.

In reverting to the remaining processes of the print-work, it must be noticed, that when the goods have passed through the weld or madder-copper, they are usually carried to a boiler containing wheat-bran and water, in which they are winched for a considerable time, for the purpose of freeing the white grounds from the stain which they had acquired from the madder or the weld. This process always impairs, in some measure, the intensity of the colours; [branning has also the effect of giving a pink hue to all madder reds. But it is not generally known what a peculiar richness may be imparted to madder-colours, by raising them with a mixture of bran and madder; that is, by mixing a portion of bran with the madder in the first instance. Mr. Parkes tells us, that he has sometimes produced colours in this way whose brilliancy has astonished him. The operation of the bran in producing this effect will be explained hereafter;] but it is a necessary operation, as there is no other mode so convenient for removing the stain which is always given to the white

part of a print by the madder, the bark, or the weld, which has been used in dyeing it.

It frequently is the case, however, that goods will not bear to be sufficiently branned to clear the whites entirely by that one operation; [the temperature at which the operation of branning is performed, is very important. If hark yellows are dyed at 100°, it is customary to bran such goods at 115° or 120°, as it is a principle always to bran at a higher temperature than the goods are dyed at. Madder-work must be branned at a boiling heat;] such goods, therefore, are partially cleaned in the branning-copper, and are then laid on the grafs for some days, till they become perfectly clean.

But within a few years a new method has been introduced, which consists in immersing the pieces for a certain time in a very weak solution of one of the bleaching salts, such as oxymuriate of potash, soda, or magnesia. [A Scotch house of great consequence had practised this method a considerable time; and in the year 1812, a person visited Lancashire for the purpose of instructing the English printers in the method.] This simple process, which effects in a few minutes what would require more than as many days in grafs-bleaching, is now much practised, and promises very soon to supersede crofting entirely. This is a most important improvement, as some of the large printers formerly required as much land to spread out their goods upon, as would make a farm of a very considerable size.

Besides the kinds of calico-printing already mentioned, there are others which it will be proper to notice in this place. Of these, what is called *resist-work*, is now done in considerable quantities. It is conducted in the following manner:

A certain preparation of copper, mixed either with flour-paste, with gum, or with pipe-clay and gum, is printed on the calico, in any shape or of any pattern that may be desired. [The sulphate, the nitrate, the muriate, and the acetate of copper, have all been employed for preparing the resist-paste; but the sulphate is the best for the purpose; unless a very concentrated solution of the four salts were prepared by successively dissolving each of them in pure water.] When this is sufficiently dry, the goods are repeatedly dipped in the blue vat till they have acquired that depth of tint which may be required; and then, when they are washed, and passed through diluted sulphuric acid, those parts which had been printed with the preparation of copper, are found to be a good white; the preparation having effectually resisted the operation of the indigo, [the art of making an indigo-vat consists in forming such a mixture of lime and sulphate of iron as shall most effectually deoxygenize the indigo; as indigo has no affinity for cloth in its natural or oxygenized state. Hence, those parts of a piece which are printed with a solution of copper will never be dyed blue in one of these vats; because the deoxygenized indigo becomes oxygenated the moment it touches the copper, which parts with its oxygen to the indigo, and occasions it to become insoluble, and consequently incapable of forming a dye. Thus, while sulphate of iron has the power of deoxygenizing indigo, sulphate of copper, or any other salt of that metal, is incapable of retaining its oxygen, whenever it comes in contact with that singular substance in a state of deoxygenization; and it is a curious instance of the different degrees of intensity by which oxygen is held by the different metals;] though all the other parts of the cloth have received a permanent dye. The various deep blue calicoes with white spots or white figures, which are now so common, are generally done in this way; and by a similar management with subsequent dyeing in madder, weld, or

bark, figures in red or yellow are exhibited upon a blue ground.

In some particular styles of work, the operation of certain colours is refitted by means of stopping out with wax; but this is too expensive a method to be adopted often in these times, when it is the object of every manufacturer to finish his prints at the least possible expence. [In printing those silk handkerchiefs called *Bandanas*, a process called waxing is still followed. It consists in making a preparation of tallow and rosin very liquid by heat, and in printing it in that state with a block upon the silk. When such goods are passed through the blue vat, those parts which are covered with the tallow and rosin are preserved from the action of the indigo, and remain white, while all the rest is dyed a fast blue. The method afterwards taken to discharge a part of this blue, and produce yellow, orange, &c. will be mentioned hereafter.] Formerly this mode was very generally practised, and wax [in the East Indies wax is still used for preserving the whites in calico-printing] was consumed in very large quantities by this process. [A very singular-looking substance was discovered a few years ago near Stockport, which being handed about from one to another as an undescribed substance, created considerable interest in that neighbourhood. Every body supposing it to be a natural production, specimens of it were sent to a variety of persons into various parts of the kingdom, for their opinion and analysis, and among others a portion was sent to Mr. Parkes. However, after every one had been busily engaged in examination and conjecture respecting this unknown substance, it was announced, that some seventy or eighty years before a calico-work had stood on the spot where the article was found, and that this was nothing more than a large heap of of the refuse compound of flour, wax, and gum, above-mentioned.]

The reader will perceive that these *refits* are employed for the purpose of preserving certain parts of a piece white, and of giving other varieties to those goods in which blue is the predominant colour: but if the ground is to be white, and the piece is only to have one small object [a technical term, belonging to this branch of manufacture] in indigo blue, such as a single sprig, then a different management is necessary, and the colour is imparted by a process which is called *pencil-blue*.

Here the indigo is deoxidized by means of *orpiment*, which is a sulphuret of arsenic; and formerly, whatever objects were done with it were put in by means of a *pencil*: hence its name, *pencil-blue*. [Pencil-blue is composed of the following ingredients, *viz.* Ten ounces of indigo finely ground in water; twenty ounces of quick-lime in lumps; the same quantity of potash of commerce, or the impure sub-carbonate of this alkali; and ten ounces of orpiment. These proportions require one gallon of water, and the whole is to be thickened with gum fenegal.] See COLOUR.

Another kind of process remains to be noticed, called chemical discharge-work. Here the cloth is first dyed of some uniform colour, by means of a mixture of iron-liquor, and some one or more of the common vegetable dyeing substances; and calicoes thus prepared are said to be dyed of self-colours. They are then washed and dried; and when properly pressed or calendered, they are fit for receiving any pattern whatever, according to the artist's taste or design.

This is generally effected by means of the mineral acids, which are previously composed for the purpose, by dissolving in them a portion of one or more of the metals, according to the nature of the dye which is intended to be discharged, or of the colour to be produced. In doing this, care is taken that the discharging liquor be made so as to be capable of

dissolving the iron which is contained in the dye, and which is always used in such quantity as to cover, or at least to disguise in a great measure, the other colour or colours which had been employed with it, and at the same time to act as a mordant in beautifying and fixing these colours.

Thus a piece treated with a decoction of Brazil-wood, and dyed black by being padded [by the term *padding* is understood the operation of passing the pieces from a roller through a trough containing a solution of iron, or any other mordant. *Bloching* is another term used in calico-printing, and is synonymous with padding] with iron-liquor, if, when dried, it be printed with a peculiar solution of tin, the ferruginous portion of the dye will be dissolved, and the printed part will instantly be converted from a deep black to a brilliant crimson.

In the same way an olive-coloured calico, dyed in a solution of iron and a decoction of weld, will as quickly be changed to a bright pale yellow; and the various drabs and flates of every shade which have iron in their composition, will undergo as sudden a change by the same treatment; though the colour of the figures produced on them will depend on the materials with which the cloths were originally dyed. Even the deepest gold colours, or strongest buffs, if produced by iron only, may, by a peculiar preparation of tin, be discharged; and such parts of the cloth as have been treated with this metallic solution will be restored to their pristine whiteness.

By similar management, calicoes dyed of a light blue in the indigo-vat, then run through sumach and copperas, and finished in a bath of quercitron bark and alum, may have figures of a bright green imparted to them. Here the green is originally formed by means of the indigo-vat and the bark, though it is enveloped by the iron of the copperas, which overcomes the other colours, till the solution of tin is applied, which removes the iron from those particular parts, and gives a brilliancy to the remaining colours which they would not otherwise have possessed; the tin being a powerful mordant for the bark, by which the yellow of the green is produced.

Again, a good self-colour may be given to calicoes, merely by dyeing them in sumach and copperas, and then running them through an alkaline solution of annatto; and here the figures produced by the application of a colourless solution of tin will be of a bright orange. But it is needless to enumerate more instances, as the workman accustomed to a dye-house will have little difficulty in varying these in a thousand ways, when he becomes acquainted with the nature of the solution of tin which he employs.

The whole of this, however, refers to that branch of discharge-work only, where all the purposes are attained by dissolving the iron which makes a part of the colour that is intended to be discharged; whereas, the finer and more expensive work is done in a different way, and by a process which it will be necessary for us presently to describe.

In the mean time it may be proper to remark, that there is an objection to the particular kind of chemical discharge-work of which we have been speaking, namely, that it is not perfectly fast; that is, the goods produced in this way will not bear such frequent washing, as those which are done by the bath of madder or bark.

It is certainly an object of great national importance to give a permanency to the calico-printing of the country; [to this end great improvements have lately been made in the method of grinding madder-roots, by separating the inferior parts, and dividing the whole into two or three different qualities. Thus the printer is enabled to apply the finest, which in this way is made equal to Dutch crop-

madder, to his best work, and the other is laid by for inferior purposes;] and a great deal of very excellent printing is now done in various parts of the kingdom, especially the best chintz-work and other furniture patterns. But, in what is called fast-work, there is a great variety of qualities, and some of it little deserves the name of permanent.

The mention of permanent colours reminds us of a very valuable green which was invented a few years ago by a Mr. Islet of London, and which deserves to be noticed by us. This colour, which was secured to him by his majesty's letters patent, was produced by printing ground indigo, mixed with a peculiar kind of solution of tin, and in then fastening the indigo within the fibres of the calico by means of that process, which is well known to printers by the technical designation of *china-blue dipping*. [China-blue is produced thus: Indigo ground fine, and then thickened, is printed upon the cloth, and afterwards it is dissolved, and chemically united to the fabric, by alternate immersion in a solution of sulphate of iron and in lime-water. A description of this process has already been given very much in detail, in our eleventh volume, part ii. under the article *DIPPING*, in *Calico-Printing*.] After this the goods are to be dyed in a copper of bark or weld, which converts the blue to a green, and the whites are to be cleansed by croft-bleaching, &c.

Upon this very ingenious process, Mr. Parkes has the following observation. "Having," says he, "formed a very high opinion of this invention, I procured several interviews with Mr. Islet, soon after he obtained the patent, and from him was fully informed of the whole process. — This I have since repeated for the purpose of verifying the detail in all its branches; and I am satisfied that it is one of the most beautiful and permanent colours that has ever been fixed upon cotton."

There is, however, another mode of producing very beautiful blues which has been much practised lately, and therefore deserves notice. This consists in printing some solution of iron, and then passing the goods through a very dilute and neutral solution of prussiate of potash. The prussian blue which is thus formed upon the cloth may be rendered tolerably permanent by a variety of expedients, and this by means of any of the yellow dyes may afterwards be formed to any shade of green or of olive.

In returning from these digressions we must not forget to revert to that other kind of discharge-work which we have engaged to describe, and which we will now attempt as concisely as is consistent with perspicuity and correctness.

Here, the agent which is employed is the citric acid, and this is used in various states of concentration according to the purpose to which it is to be applied, and the strength of the ground intended to be discharged. It is chiefly employed for the production of white figures upon self-coloured grounds produced by madder and sundry other dyes. For this intention the acid, in whatever state of concentration it may be, is mixed with either gum or with paste, [when citric acid is used for resist-work, it is always mixed with gum fenegal and pipe-clay. The clay gives it a greater body, and likewise acts mechanically as a resister,] to a proper consistency for the block, the plate, or the cylinder, and from thence it is transferred to the piece; and wherever it attaches, the mordant, whether iron or alumine, is discharged, and a delicate white arises in its stead. [It should be understood, that the discharge is printed upon the mordants before the goods are dyed. In using citric acid for this purpose, a portion of one of the mineral acids is sometimes mixed with it.]

The acid here referred to is produced from the juice of

limes or lemons, and formerly it was not employed by the calico-printer until it was reduced to the utmost point of concentration, and appeared in a crystalline form. Even then, it was not thought sufficiently pure, but was dissolved again, and redissolved and recrystallized, till it became as white and pellucid as any other pure salt in a crystallized state, and was then generally sold for 36s. the pound, at which high price it could only be employed on the best styles of work. Now, however, it is oftener used in the brown, or first state of crystallization; and some of the larger printers purchase lime juice, and concentrate it themselves; and in many cases, they use it largely both for discharge and resist work, without ever crystallizing it at all. More on this subject may be seen in Mr. Parkes's Essay on Citric Acid, in vol. iii. of the Chemical Essay, page 1—118.

This mention of discharge-work by citric acid, [Mr. Thomson, who has a print-work near Clitheroe, has taken out a patent for discharging the Turkey-red dye by means of the citric and oxymuriatic acids; and the work executed in this way has a very pleasing effect,] reminds us of another species of discharge, which is employed by the printers of Bandana handkerchiefs, and which we are under the promise of noticing before we conclude this memoir.

The agent which these printers employ is the nitrous, and sometimes the nitro-muriatic acid. It is used for the purpose of putting yellow figures upon blue silk handkerchiefs. The following is the process which is principally adopted.

Aqua-fortis, or nitro-muriatic acid, of such a strength as is suitable for the kind of blue which is intended to be discharged, is mixed either with gum tragacanth, or with flour paste, to a proper consistence, and in this form it is printed on the silk, by means of a common block, on which the intended pattern is cut. The consequence of this is, that wherever the acid attaches, there the original colour is discharged, and a yellow dye is produced in its place. The pieces are then steamed, by passing them over a vessel containing boiling water, which gives brilliancy to the colour and finishes the operation.

If a stronger dye than the usual yellow, or even a deep orange be desired, all that is necessary is to immerse the goods, for a moment, in lime-water, or in a solution of lime and potash; and by varying the proportions of these ingredients a great variety of shades may be produced.

Recollecting, however, that this is a paper professedly on calico-printing, we must not deviate too far from the path we have prescribed; otherwise, there are many processes in the printing of silks which are curious and interesting, on which we might copiously expatiate. The Bandana handkerchiefs which are printed upon cotton in imitation of India goods, are produced by a very different process, and which we have already described under the article *Discharging of Colour*, in vol. xi. part ii.

Having been speaking of yellows, it may be worth mentioning, that there is a mode of producing yellows on calico which is not very frequently practised, and yet has a very good effect. The process is as follows:

A strong decoction of bark, thickened with gum tragacanth, is to be mixed with a portion of very pure muriate of tin, and this, when printed with the usual management, will produce a colour of great brightness and durability. We mention this the rather, because very many pleasing effects may be obtained by this method which cannot be produced in the usual way, by means of the acetate or alumine, and any of the yellow dyes that may be employed with it.

There is one very important advantage which this mode

possesses, *viz.* that should it be necessary to pad a piece in diluted acetate of alumine to obtain a pale lemon ground, the yellow figures, previously done by the above process, will not give out any part of their colour to the second mordant; whereas, whenever a strong yellow has been produced in the common way, the pattern is very apt to spread and become irregular, and oftentimes to stain the ground, when the piece comes a second time into the acetate of alumine.

Observing that the treatise from which we have made such copious extracts, contains no particular directions for the preparation of that superior kind of calico-printing called chintz-work, we applied to Mr. Parkes upon the subject, and he has furnished us with an original communication to supply that deficiency, which is as follows:

The term chintz-work is descriptive of that kind of calico-printing which is employed for beds, window-curtains, and other furniture, and it differs more in the richness and variety of the colours, than in any other circumstance.

In relating the processes by which these beautiful prints are produced, we shall suppose the calico to be already properly bleached and calendered, ready to receive the impressions of the block. The first thing then to attend to is, to apply the mordant for the colour which is intended to be imparted in the first instance. Thus if a black be designed, a mordant of acetate of iron, commonly called iron liquor, is thickened with gum, and printed upon the cloth in any pattern that may have been selected for the purpose. If this same mordant be diluted with water, it will form a proper mordant for a purple; and the same, still further diluted, will, when it comes into the dyeing copper, form a lilac. In this way, all the varieties of shades, from a pale lilac to a strong purple, and from purple to a black, may be produced by acetate of iron diluted with various proportions of water, and then dyed with madder.

In like manner, a colourless solution of acetate of alumine thickened with gum or flour paste, forms a mordant for dark red; if diluted with water it makes a common red; and by diluting it further and further every shade of pink may be produced. Again, by the admixture of acetate of iron, and acetate of alumine, a mordant for chocolate colours, maroons, &c. is formed, either approaching to the purple or the red, according to the admixture; that is, according to the proportion of either of these original mordants which may predominate in the mixture.

When these several mordants have been printed upon the calico, they are allowed to dry for two days or more in a stove or drying-house; they then go through the operation of dunging, which consists in rinsing them in warm water, in which a little cow-dung is diffused, as has been already described. When the pieces are sufficiently dunged, which is not the case till all the superabundant mordants are removed, they are well-washed in clean water, and then boiled in a decoction of madder, until the madder-bath is exhausted. In consequence of different mordants having been applied to the cloth, this one boiling in the madder-liquor will at once produce all the colours above-mentioned. When the pieces are thus dyed, they are to be rinsed in cold water, and laid upon the grafs to bleach. By this exposure to the air for a few days, the whole of the ground to which none of the mordants had been applied, will become perfectly white.

The processes which have now been detailed, will produce what is called common chintz-work; but if it be desired to make the goods still richer, by the addition of yellows, bright olives, drabs, &c. the cloth must undergo another series of operations, which may thus be described.

Upon those parts of the calico which still remain white, any of the above mordants may be printed, according to the effect designed to be produced, after which all the preceding managements are to be repeated, except that instead of boiling in a decoction of madder, they are to be immersed for about half an hour, more or less, in a warm decoction of quercitron bark, the *Quercus nigra* of Linnæus; a most important dye-wood, introduced by Dr. Bancroft, and which is found to give out a much brighter colour to tepid water, than it does when treated with boiling water, or with water nearly approaching to that temperature.

The effect produced upon these prints by an immersion in a lukewarm decoction of this American bark, will be quite different from that produced by the madder; upon those parts of the cloth where the mordants have been printed which before produced a black, a dark olive only will be apparent, and instead of pompadours will be drabs, and instead of reds we shall have yellows, which will vary in intensity according to the strength of the aluminous mordant.

Again, a further variety may be given to these prints, if the yellow mordant, or acetate of alumine, be applied to any of the colours which have already been dyed with madder; but this must be done before the pieces are immersed in the decoction of bark. This application will convert the reds and pinks into different shades of oranges, and the lilacs into cinnamon colours. By means of these different processes an endless variety may be given to the goods, and a calico-printer of taste will never be at a loss how to produce a pleasing effect, whatever may be the patterns which he has to imprint upon the cloth. This second immersion in the dyeing vessel will, however, give a yellow tinge to the remainder of the whites, but a short exposure on the grafs will obliterate it.

When chintz furniture-prints are designed to have as much variety of colouring as possible, a part of the remaining white is often coloured blue or green, or of any shade between those colours, by a still different process. This is done with what is called pencil-blue, which is a preparation that has already been described. The blue is given by putting in the prepared indigo with a pencil; and the green is produced by pencilling some of the same colour over certain parts of the pattern which has already been dyed yellow. When these colours have been imparted, the printing is said to be finished, and the pieces are hung up to dry for at least twenty-four hours, after which they are rinsed thoroughly in cold water; and when they have been dried with care, they are properly calendered and put up for sale.

Nothing now remains but to notice an improvement which has been made of late years by the introduction of cylinder-printing, and which has the advantage of superior accuracy and neatness, as well as of great expedition.

The machines which effect this are rather complicated and expensive; but they are so contrived that the cylinders on which the patterns are engraved, furnish themselves with colour during their revolutions; are kept clean by a steel knife, or *doctor* as it is called, passing over their surfaces the moment they have charged themselves with the thickened colour; and they have such a pressure given to them, either by means of screws or levers, which can be tightened or slackened at pleasure, that the whole surface can be made to deposit its colouring matter with the greatest certainty and exactness on the cloth, while this rolls over it in succession, from one end of the piece to the other.

These cylinders, which are made of copper, are from eighteen to forty-two inches in length, according to the width of the calico to be printed, and three and a half to

five inches in diameter; and these maffy rollers have the patterns enchased upon their surfaces, in the same way as a pattern is cut upon a flat plate of copper, that is intended to be employed in copper-plate printing. As these cylinders are made with plates of copper hammered into a circular form and joined by brazing, great loss has sometimes been sustained by the engraving giving way upon the brazed joint. To obviate this, a patent has been lately obtained for boring the copper cylinder from the solid metal in the modern way of boring cannon.

Many of these machines are now contrived so as to carry two of these cylinders, each of which has a trough of colour attached to it, by which means two different colours may be printed on the same calico, at one and the same time.

Mr. Adam Parkinson of Manchester has lately invented a machine capable of printing at one time, by means of one cylinder and two surface-rollers, or by two of the former and one of the latter, three distinct colours.

These machines have not only the excellence of printing more correctly than can possibly be done by means of the block, but the saving of time and labour which they afford is great indeed. A piece of calico which would take a man and a boy three hours to print with one colour, or six hours to finish with two colours, may by this means be done in three minutes, or three minutes and a half, and then much more completely than could even have been imagined before the introduction of this invention.

Besides these cylinders there are others which are called *surface-machines*, which contain cylinders of wood, and which have the pattern formed upon their surfaces in relief, exactly similar to the blocks already described. These are employed in particular styles of work, especially in light ground-work, and for certain kinds of resist and discharge work.

In light work, the white grounds are apt to be soiled by the cylinders: hence surface-machines were contrived, and these are not liable to the same objection. Cylinder-machines are more commonly employed in those styles which are full of colour and leave but little white.

It must be obvious to every one who is acquainted with the subject, what an astonishing facility these machines have afforded to the production of printed calicoes; and also what an advantage they give to the British printer in foreign markets.

But we cannot conclude without expressing our fears, that even these facilities may eventually be the means of doing a serious injury to the trade, and of destroying that confidence in the goodness of British prints, which has hitherto been generally felt in every market on the continent, and also in every part of the New World, wherever they have been introduced. We refer to that mode of printing which has lately been adopted, and which consists in precipitating the colouring matter from logwood, and from other *fugitive* dyes, and in printing these on the cloth, without any mordant or previous preparation whatsoever. Thousands of pieces of this sort have been finished at the low rate of one penny the yard, including every expence of colour, paste, and printing. These articles, it will scarcely be credited, are dried up immediately from the printing-machines, and are shipped abroad, without even being washed off.

To *wash off* is a technical phrase. It means the soaking and rinsing the pieces in water, in order to dissolve and remove whatever gum or paste had been employed with the colours in printing them.

Such goods, wherever they go, must produce great dis-

satisfaction; for they will neither endure the rays of the sun nor moisture. The first shower of rain to which they may be exposed, will not fail to wash out the pattern, and reduce them to a worse state than that of plain white calicoes.

In the reign of queen Elizabeth, an act was passed to restrain the use of logwood in dyeing, on account of the fugitive nature of its colour; and if this degrading kind of printing be continued, the interference of the legislature will again become necessary, or the foreign trade will, from this cause alone, be entirely lost to the country.

PRINTING, *Cylinder*. See the preceding article.

PRINTING on *Porcelain*. The art of printing, particularly as it applies to books, has, from its incalculable benefits and vast importance, excited at once the profound admiration and gratitude of the world; and this inestimable discovery has been claimed by several individuals, alike anxious for the honour of giving to mankind at large the advantage of a rapid and economical diffusion of delight and instruction. The *first* idea of *types* was very probably given by the *Roman potters*, who were in the habit of stamping their names in *raised* characters on their vases, &c. The letters on this plan were, in fact, *models* of the types used by the first printers; and it appears singular that the idea of adapting such models by the medium of ink, to the common purpose of multiplying words and sentences, should not have come into use until about the year 1442.

It will appear, on consideration, still more singular, that after the introduction of engraving on wood and copper, (which was in use at the same time with letter-press printing,) the art of transferring impressions of ornamental designs, from the copper-plate to the surface of porcelain or pottery, was not discovered till about the year 1760.

The Royal Porcelain Works in Worcester, belonging to Messrs. Flight, Barr, and Barr, are the only establishment that claims the honour of inventing this admirable and ingenious process. We can find no mention of this art in the annals of this or any other country prior to this period. It was practised with great success for many years in the works alluded to; and besides the demand for home consumption, large quantities were exported to Holland. In the year 1788, his present majesty Geo. III., and his royal consort the queen, with the princeps royal, the princeps Augusta, and the princeps Elizabeth, visited the Worcester Porcelain Works, and particularly noticed this ingenious branch of the art of decoration. The royal party were much gratified by the compliment paid them, in the striking off impressions from two copper-plates with the likenesses of the king and queen, which had previously been engraved by direction of the proprietors, in order to exemplify the nature of the operation. The secret of the printing was, about the year 1781, conveyed from the works at Worcester into the potteries of Staffordshire, and has proved of infinite service in extending this branch of national commerce, and affording employment to the numerous population in that part of the country. The common British blue and white printed earthen-ware is now held in high esteem in foreign countries, from its cleanly and neat appearance, besides its being in general use at home. This art is certainly best confined, as in the present day, to the inferior fabrics, such as earthen-ware, as the material on which the print is made is reasonable, and can be rendered at a price which suits the convenience of the consumer for all common purposes. The method, as invented and adopted by the original proprietors of the Worcester Porcelain Works, is as follows:—The engraved copper-plate having

first been warmed on the stove, is prepared to receive the colour, which, being previously mixed with oils of a proper consistency, is then rubbed into the engraved lines, and the superfluous quantity of colour is carefully cleaned from the surface of the plate. The paper, which is very thin, and manufactured for the purpose, is then laid on the plate, and delivered to the pressman, who places it on a plank covered with warm flannels, and being fixed between two iron cylinders, it is drawn through by turning a wheel, exactly on the plan practised in taking off copper-plate prints. The paper bearing the clear-coloured impression is now removed from the copper-plate and delivered to the printer, who fixes the piece of porcelain in a vice, to keep it steady; and the printed paper is then rubbed with a wooden tool, covered with flannel, till the impression is completely transferred to the surface of the biscuit, or *unglazed* porcelain. The operation of rubbing on the impression being completed, the porcelain, with the paper left on the surface, is thrown into a tub of cold water, and in a short time the paper delivers itself, and leaves the print. The ware is now placed out to dry, and is afterwards carried to the kiln, where the impressions are burnt in. It is then dipped in the liquid vitreous substance called the glaze, is burnt a second time, and the colour, which is the oxyd of cobalt, (and most generally used,) comes out a neat blue, perfectly secured under the glaze.

An *improved method* of printing, comparatively of very recent invention, was introduced under the direction of the late Martin Barr, esq., and is now carried on in the Porcelain Works at Worcester, and is much admired for the *excellence* of the engravings, and the great beauty of the impressions. On this plan, the printing-press and stove are not necessary, as the engraved plate is charged with a prepared oil by the printer, who cleans the surface of the engraving with the hand; and instead of paper, a *bat* of

glutinous consistency is cut out and laid on the copper-plate, and is so ductile as to adapt itself to the form of any vessel intended to be printed; and by the simple pressure of a stuffed leathern ball *with the hand*, produces a perfect impression of the subject *in oil* on the smooth side of the bat. The ware being rubbed dry and clean, the bat is now gently pressed with the leathern ball on the *glazed* surface of the porcelain, and when removed the impression appears complete, *but only in oil*. The colour, in form of a powder, is then lightly moved over the oil impression with a piece of carded cotton, and the print completely cleared of all that is superfluous. The porcelain is afterwards carried to the enamellers, who finish the design by adding some decorations in gold; and it is then passed through the enamelling kiln, where the oil is evaporated by the fire, and the colour, which is always a mineral preparation, unites firmly with the glaze, and becomes perfectly durable as the tints laid on with the camel's-hair pencils by the painters. The great advantage of this plan is, that the engraving can be executed *much finer* for the smooth surface of the *glazed porcelain*, than for the coarser blue and white prints, (which are laid on the *rough unglazed surface*,) as the glaze is capable of receiving the *finest touch* the artist can put into his engraved plate. Messrs. Flight, Barr, and Barr, the proprietors of these works, have in consequence introduced beautiful engravings of figures from the antique, besides designs in landscapes, flowers, shells, &c. which reflect no small degree of credit on this branch of the art of printing. Considerable quantities have been exported to the East and West Indies; and where economy is the object of the consumer, this style of decoration suits very well, however deficient in richness of effect and elegance, to the more elaborate production of enamelled designs, executed in these interesting and highly-respectable works.